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GEOLOGY FROM THE ISOSTATIC VIEWPOINT

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THE mysterious earth has puzzled untold multitudes for tens of thousands of years. Each generation has struggled for an explanation of the history of the earth as written in stone, and this history has been only partially translated or deciphered even to the present time, when so much is known of such things as radio, flying machines and the constitution of the atom.

To-day the atom which can not be seen, even with the most powerful microscope, is more completely known than the earth. How was knowledge of the atom gained? By indirect methods and scientific deductions. What is known about the interior of the earth and much of its surface material is gained in the same way.

The earth is now receiving more attention from scientists than ever before. They want to know how deposits of oil, coal and ores were formed and how they may be discovered; the causes of earthquakes which occur daily, some of them most disastrous to man and his works; the causes of the great changes in the elevation of the earth's surface; and many other things which are either interesting or important.

In each year more than five thousand earthquakes register their tremors on the many seismographs in operation throughout the world. Some quakes are felt by human beings, but the vast majority are known only from the record made on the seismograph. What is the relation of the small quake to the large one? Are there areas free from even the feeblest quake? Shall we ever be able to predict the time and place of destructive ones? All these questions are being studied, and while they may never be definitely solved, yet much light will be thrown on them by the accumulation of accurate data as time goes on.

In addition to our knowledge of the surface features of the earth, consisting of mountains and plateaus, valleys and coasts, oceans and lakes, we know that the earth is as rigid as steel, but that in spite of this, under gravitational forces it yields like putty; mountains and continents float; there are no "everlasting hills"; the nucleus of the earth is not contracting and leaving the crust "up in the air," to collapse later on and buckle into mountains; the earth does not have a boiling and bubbling center, with volcanoes as smokestacks; and earthquakes are not caused by worldwide processes, concentrating their forces for any particular quake, such as the destructive ones in Japan and at San Francisco and the one on February 28th of this year, which created so much in-

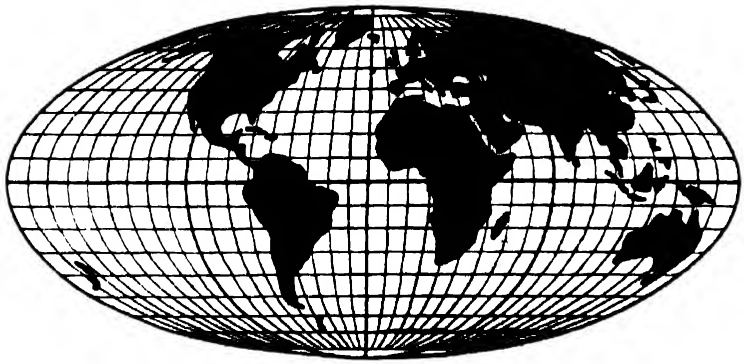

FIG. 1. THE EARTH'S SURFACE IS ABOUT 200,000,000 SQUARE MILES OF WHICH 57,000,000 ARE LAND. THE LAND AREAS ARE USED FOR DETERMINING THE EARTH'S SHAPE AND SIZE, AND IN DECIPHERING THE GEOLOGICAL HISTORY OF THE LAST FIFTEEN THOUSAND MILLION YEARS.

terest and some consternation in the eastern part of the United States.

Earthquakes are due to local forces, originating from change in density of the material of the earth's crust under the region or in the disturbance of the outer portion of the earth by the processes of erosion and sedimentation.

How do we know that these things are true or false? By the processes of the most exact measurement followed by analysis and deduction. A greater quantity of exact measurements with which to study the earth's material has been made during the past century than during the previous thousands of years that man has been on the earth.

The data consist of the determination by observations on the stars of the latitudes and longitudes of thousands of places on the earth and measurements by triangulation of distances between the astronomic stations; the value of the earth's pull or gravity at several thousand places; observations of the time of transmission of earthquake tremors through the earth's materials; the determination of the variation of the relation between the axis of figure and the axis of rotation of the earth; and the observations of the tides of the oceans and of the surface of the land caused by the irregular pull of the moon and sun as the earth rotates.

These data, on their face, do not seem to give much promise as a means of discovering anything of the condition of the earth's material or the processes which have modified its surface, but much has been learned from them.

From the measurements of distances by triangulation and the astronomical observations on the stars, for latitude, longitude and azimuth, the shape and size of the earth have been determined with sufficient accuracy for all practical purposes and most scientific ones. The geodesists are still endeavoring to arrive at a closer value to the true dimensions as geodetic and astronomic data accumulate.

It was with the observations and measurements used to determine the figure of the earth that one of the great discoveries of science was made. This is that the earth's crust is resting on material which acts as if it were plastic. The crust floats on this material as the great ice field of the Arctic floats on the waters of that ocean.

Suppose that, in a basin of mercury, there are placed in an upright position several blocks of different metals, each metal lighter in density than the mercury, and each block with the same weight and the same cross-section. They

would all sink to the same depth. The lower surfaces would form a plane and the upper surfaces would be irregular; the lighter the metal the higher the block would stand above the surface of the mercury.

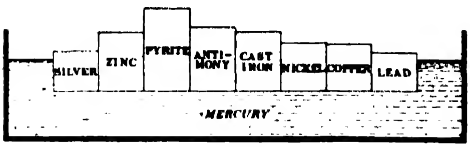

FIG. 2. BLOCKS OF LIGHT METALS OF EQUAL MASS AND THE SAME CROSS-SECTION PLACED UPRIGHT IN A BASIN OF MERCURY WOULD SINK TO THE SAME DEPTH. THIS IS A SIMPLE ILLUSTRATION OF HYDROSTATIC EQUILIBRIUM. THE THEORY OF ISOSTASY IS BASED ON THE PRINCIPLE ILLUSTRATED ABOVE.

By imagination, let the earth's crust be cut into blocks by vertical planes, making squares of say 100 miles on a side. Suppose there were no friction between them. Then they would remain in place without appreciable movement, for each one weighs the same as each of the others. The earth's crust is in equilibrium and floats, just as the blocks of metal float in the mercury.

This theory regarding the earth's crust was first propounded by Pratt, a noted British geodesist and mathematician, nearly seventy years ago, and the idea was hinted at also by Airy.[1] Pratt was led to this theory by the study of the geodetic observations and measurements in India with which he was attempting to determine the dimensions of the earth. The theory was not taken very seriously until Dutton[2] in 1889 delivered his famous lecture in Washington, D. C., at a meeting of the Philosophical Society in which he gave the theory the name *Isostasy*. This term is derived from two Greek words, meaning "equal standing" or "equal pressure."

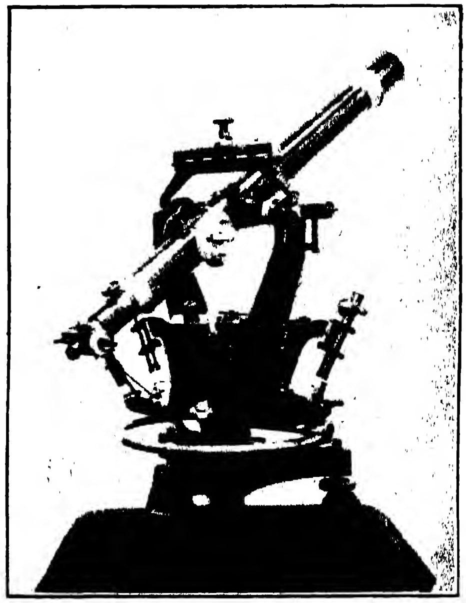

FIG. 3. THE THEODOLITE IS USED BY GEODESISTS IN MAKING MOST ACCURATE OBSERVATIONS FROM WHICH THE SHAPE AND SIZE OF THE EARTH ARE COMPUTED. HELIOGRAPHS AND SIGNAL LAMPS, STATIONED ON MOUNTAIN PEAKS, HAVE BEEN OBSERVED WITH THIS INSTRUMENT FROM DISTANCES GREATER THAN 150 MILES.

Following Dutton, many geologists wrote about the theory of isostasy, some upholding and others condemning it. The first serious attempt to test the theory by actual measurements was made by Putnam[4] in the nineties when he was a member of the U. S. Coast and Geodetic Survey. He used for this purpose a few gravity stations, widely scattered over this country. Putnam's conclusion was that the United States, as a whole, is in isostatic equilibrium, but that mountain ranges are probably supported by the crust as extra loads. Gilbert,[4] discussing Putnam's results,

[1] J. H. Pratt, Philosophical Transactions of the Royal Society of London, Vol. 145, page 52. G. B. Airy, Philosophical Transactions of the Royal Society of London, Vol. 145, page 101. J. H. Pratt, Philosophical Transactions of the Royal Society of London, Vol. 148, page 745.

[2] C. E. Dutton, "On some of the greater problems of physical geography," *Bulletin*, Washington Philosophical Society, Vol. 11, pp. 51–64.

[4] G. R. Putnam, "Relative determinations of gravity with half-second pendulums and other gravity investigations, with notes on geological formations by G. K. Gilbert," U. S. C. & G. Survey Report for 1894, App. 1.

decided also that the earth's crust holds up mountain systems.

Following Putnam, Hayford made investigations resulting in two reports[5] on the figure of the earth and isostasy. He proved the theory to be substantially true for the United States. He used hundreds of astronomic stations and thousands of miles of arcs of triangulation in the United States, largely resulting from the work of the Coast and Geodetic Survey.

Hayford found that not only the United States as a whole is in isostatic equilibrium, but that even portions of the earth's crust of moderate size are in equilibrium. He found that the crust of the earth within which abnormal densities occur extends to a distance of about seventy miles below sea level.

[5] J. F. Hayford, "Figure of the earth and isostasy from measurements in the United States," and "Supplementary investigations in 1909 of the figure of the earth and isostasy." These are publications of the U. S. Coast and Geodetic Survey.

When Hayford left the Coast and Geodetic Survey to take up the duties of director of the college of engineering of Northwestern University in 1909, the isostatic investigations of the Coast and Geodetic Survey were continued by the writer with the assistance of Messrs. C. H. Swick and W. D. Lambert and Miss Sarah Beall, mathematicians in the Division of Geodesy of the Survey.

In this later work there were used the values of gravity at more than three hundred stations in the United States and over forty stations in Canada. The writer's results confirmed Hayford's and proved beyond doubt the theory of isostasy.

Briefly stated, the results of all the isostatic investigations are: The earth's crust is in a state of almost perfect equilibrium; the crust extends approximately sixty miles below sea level; the weight of a block of the crust of unit cross-section, say one hundred miles square, is the same within a very small

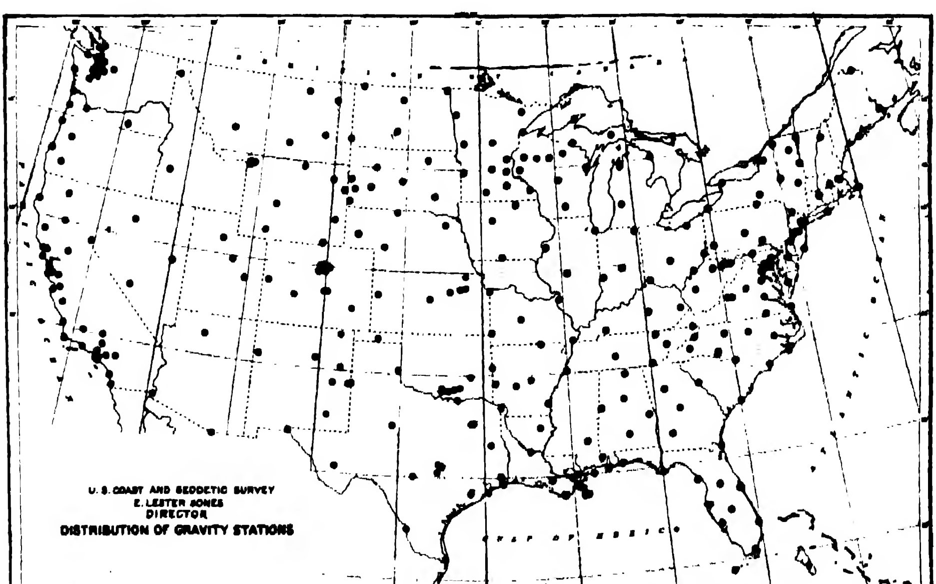

FIG. 4. HUNDREDS OF GRAVITY STATIONS IN THE UNITED STATES AND IN OTHER COUNTRIES HAVE BEEN USED TO PROVE THAT THE EARTH'S CRUST IS FLOATING.

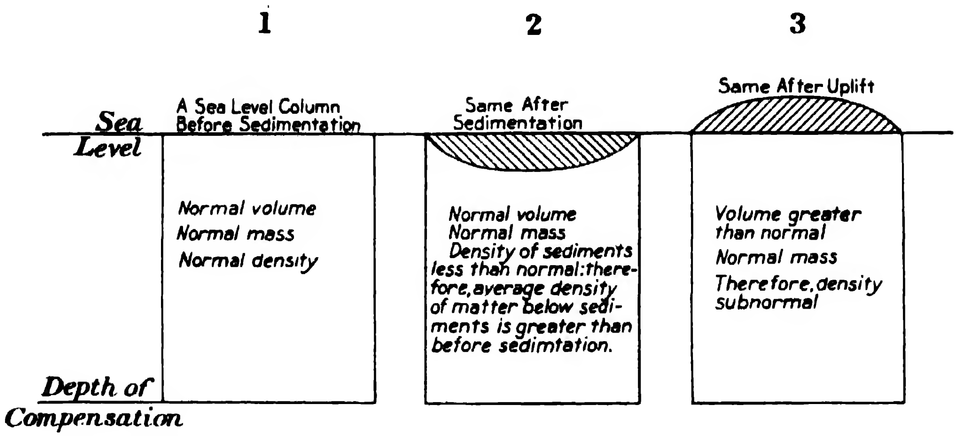

FIG. 5. THE EARTH'S CRUST IS IN EQUILIBRIUM, AND PROBABLY ALWAYS HAS BEEN SO. ASIDE FROM DEPRESSION AND ELEVATION INCIDENT TO SEDIMENTATION AND EROSION, CHANGES IN THE ELEVATION OF THE EARTH'S SURFACE ARE DUE TO CHANGES IN DENSITY IN THE CRUST.

percentage as the weight of any other unit block; the mass represented by land which is above sea level is balanced by a material lighter than the average in the crust below, just as a portion of an iceberg above water is floated by the part which is below; no mass above sea level equal to a disk of rock twenty miles in diameter and three thousand feet in thickness fails in being compensated by deficient density in the crust beneath it; the water in the oceans is compensated by material denser than the average in the crust below the oceans; unit blocks under land areas of various elevations and blocks under the oceans of different depths are in equilibrium; blocks under the oldest and under the most recent geological formations are in equilibrium, as well as the blocks under the areas of intermediate geological ages.

The work done by the U. S. Coast and Geodetic Survey has been supplemented by that of the Survey of India, which has done some notable work in testing the theory of isostasy. Its results have been published in several official reports and papers in scientific journals. The most noteworthy of these are by Colonel Sir Sidney Burrard,[6] formerly surveyor-general of India.

Some studies which will show the degree to which the theory of isostasy obtains for the areas of other countries are under way, and it is hoped that reports will soon be made of the results.

So far, we have been on sure ground. Hayford, Burrard and the writer agree and their views are supported by many others as to the existence of the isostatic equilibrium of the earth's crust in the United States, a part of Canada and in India. Since this is true of these large areas it is perfectly logical to conclude that it is true of the rest of the crust of the earth, whether land or the ocean areas.

From this point we must use indirect methods and inferences in interpreting the significance of the theory of isostasy.

[6] Colonel Sir Sidney Burrard, "Isostasy in Himalayan and neighboring regions," Prof. Paper No. 17, Trigonometrical Survey of India; "A brief review of the evidence on which the theory of isostasy has been based," *Geographical Journal*, London, Vol. 56, July, 1920; and "On the origin of mountain ranges," *Geographical Journal*, September, 1921.

Some of the results[7] of the writer's investigations diverge greatly from the generally accepted theories regarding the constitution of the earth's crust and the processes which have so altered the appearance of its surface during geological times.

The earth's crust is very weak as a structure, and does not stand up as a masonry arch carrying great loads as extra weight. If it were very strong small blocks of it would not have the same mass or weight. Tens of thousands of feet of material have been eroded from some areas, as, for instance, those occupied by the Appalachians and the Himalayan mountains. The blocks of the earth's crust under these mountains are not extra light. The materials eroded from the mountains have been carried by streams and rivers either to great valleys or to the edges of the continents and have been laid down as beds of sediments tens of thousands of feet in thickness, but the blocks of the crust under the sediments are not extra heavy.

Would not any one, considering the evidence, reach the conclusion that the blocks under the sediments sink under the added load and that the blocks under the mountains rise as materials are worn away from their surfaces? This is exactly what must happen, but how can this come about? The answer is that below the crust, something more than sixty miles below sea level, the earth's materials act as if they are plastic and are readily moved sideways when the blocks of the crust are loaded and unloaded.

There are really no such things as blocks of the crust, for the crust is solid and continuous over the whole earth. But the assumption of separate blocks helps one to study the conditions and processes, while without this assumption one would be led into much difficulty and confusion.

The material below the crust must be much hotter than that at the surface, and the lower material is under a weight of about fifty million pounds or twenty-five thousand tons per square foot. We do not know the temperature; in fact, by direct observations and measurements we do not know anything about the earth at a lower depth than about one and one half miles. Borings have been made to that depth, and they give an indication of the change in temperature down in the crust. It has been found that the temperature increases at the rate of about 50° C. to the mile. If this rate of increase were uniform, we should have a temperature of about 3,000° C. at the bottom of the crust, a temperature which at the earth's surface would be sufficient to fuse rocks of all kinds. Owing to the great pressure exerted by the crust, even the great temperature which must be below can not fuse the rocks. In fact, the inference from tidal, earthquake and latitude observations is that the material below the crust is as rigid as steel. This inference or conclusion has not been questioned. How can this material be so rigid and yet yield to the loading and unloading of portions of the crust? Here we must bring in the time element. The stresses resulting from the tide-producing forces of the moon and of the sun, the earthquake vibrations and the forces which produce variations in latitude act for very short times, for a few minutes or hours or for a day or a year. To these short stresses the material below the crust acts as a rigid body. However, the stresses resulting from the disturbances of gravitation act for thousands of

[7] William Bowie, "Some geological conclusions from geodetic data," Proceedings of the National Academy of Sciences, January, 1921; "The relation of isostasy to uplift and subsidence," *American Journal of Science*, July, 1921; "The earth's crust and isostasy," *Geographical Review*, October, 1922; "Yielding of the earth's crust," Annual Report, Smithsonian Institution, 1921.

years. To these long-continued stresses the material is plastic and yielding.

A tallow candle can be snapped by the application of a sudden strong force, but it will be bent without fracture by a small constant pressure. Every one knows how easily glass is broken, but put a long piece of glass on two supports and leave a weight on its center for a month or two and the result will be a decided bending downward. There is really no material which can not be distorted without rupture under force applied under certain conditions for a sufficient time. We may accept as an entirely logical deduction that the material under the crust is plastic to even small stress differences caused by the movement of material by streams and rivers over the earth's surface. By small I mean the equivalent of five hundred or a thousand feet of material, deposited over or eroded from an area one hundred or two hundred miles square.

Suppose two piles of boards were placed on a flat of soft mud. Each of the piles would sink to such a depth that the weight of the displaced mud would equal the weight of the pile. Suppose further that a layer of boards were taken from one pile and placed on the other, then what would happen? The first pile would rise, while the second one would sink deeper, but the surface of the first pile would be slightly lowered, for the mud coming under the pile would have a less thickness, since its density is greater, than that of the boards removed. On the other hand, the surface of the second pile would be raised a little by the addition of a layer of boards, for the mud pushed from the bottom would have a thickness less than that of the boards. At first there would be some disturbance of the hydrostatic balance of portions of the mud flat by the transference of the boards from one pile to the other, but after a few days or weeks the balance would be restored.

The earth's crust acts somewhat in accordance with the crude illustration of the piles of boards resting on or in the mud flat. But with the crust we must have a longer unit of time, a thousand or even ten thousand years. The sinking of one block of the crust under sediment will push the subcrustal material towards the blocks undergoing erosion, thus restoring the isostatic balance.

With a weak crust and plastic material below, how could the crust accumulate stresses for ten or a hundred million years due to a cooling and shrinking nucleus resulting later in convulsions which would form mountain systems by collapse of the crust and the crumpling of its materials? This is the theory of mountain building held by many geologists of the present and most of those of earlier times; it does not appear to be in accord with our present-day knowledge of the earth's crust.

The geological estimate of the time since the oldest existing sedimentary rocks were formed is about one and one half billions of years.

Sedimentary rocks result from the action of water, therefore the temperature of the earth's surface one and one half billions of years ago must have been less than 100° C. Before there were sediments, water could not have been running over the surface of the earth. The inference must be that the surface materials were hotter than the boiling point of water.

The temperature at the surface of the earth varies with the season of the year and the latitude, but the average for all land areas for a year is between 5° and 10° C. Assuming 10° C. as the temperature of the surface, then the drop during one and one half billion years is only about 90° C. If all the change could have taken place at once, the shortening of the diameter of the earth would have been about two miles and the circumference would have been lessened by only

about six miles. These changes are insignificant as compared with the great contraction of the crust since the beginning of sedimentation, computed by some geologists.

Below the sedimentary rocks which enfold the earth there are what are called igneous rocks, which presumably were fused at some very distant time. Let us assume that they were. At that time the surface temperature must have been more than 1,000° C. This temperature had to fall to the 100° C., which occurred about one and one half billion years ago. From the time that the earth's surface was molten to the time when the oceans were formed there must have elapsed many years, possibly from ten to twenty billion, during which the surface cooled to 100° C., if the rate of cooling were the same as during the last billion and a half years.

The above is a very important deduction, for it indicates that the earth's materials had enough time to do all the contracting possible under gravitational forces prior to the beginning of the sedimentary stage of the earth's existence. There may have been other sedimentary periods in the dim past, but if so no record of them has been left us.

The theory of the contracting nucleus and the collapsing crust as the cause of mountain building should be abandoned. It does not fit the accurate geodetic data, nor can it stand the usual processes of physical reasoning.

We have, then, a solid but weak crust, and an interior rigid to stresses of short duration but plastic to stresses acting through geological time. It has had sufficient time to assume a state of equilibrium under the gravitational forces exerted by its own material. Great changes in elevation of the surface materials have taken place.

What, then, are the primary causes of the surface disturbances? By a process of elimination we arrive at the conclusion that the causes are water and gravitation. The moisture falls from the air as rain, and the water runs over the land area from the high ground to the and oceans, carrying vast quantities of solid matter in suspension and solution. This material is deposited as sediment in the valleys, at the continental margins and out in the oceans. Gravitation makes the water flow down the slopes, it forces the crust down under the weight of the sediments and it forces up the lightened crust where erosion has occurred.

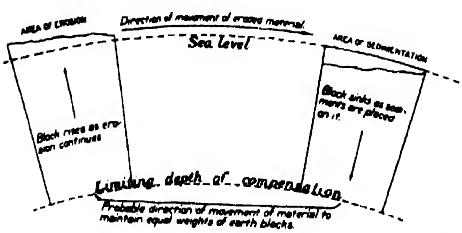

FIG. 6. THE ACTIVE AGENTS DISTORTING THE EARTH'S SURFACE ARE WATER AND GRAVITATION. THE WATER FALLING ON ELEVATED GROUND ERODES THE SURFACE AND CARRIES THE MATERIAL TO LOWER GROUND. GRAVITATION CAUSES THE WATER TO FLOW TO THE OCEANS AND IT FORCES THE CRUST DOWN UNDER THE LOAD OF SEDIMENTS AND UP WHEN EROSION HAS LIGHTENED IT.

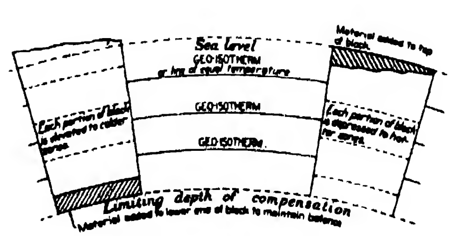

FIG. 7. DURING THE ELEVATION OF A PORTION OF THE EARTH'S CRUST UNDER AN AREA OF EROSION, EACH PART OF THE UPMOVING CRUST GOES TO A REGION OF LOWER TEMPERATURE; WHILE UNDER ACCUMULATION OF SEDIMENTS EACH PART OF THE CRUST BENEATH IS LOWERED TO REGIONS OF GRATER TEMPERATURE. THE CONSEQUENT HEATING AND COOLING CAUSE CHANGES IN VOLUME WHICH RAISE OR LOWER THE EARTH'S SURFACE.

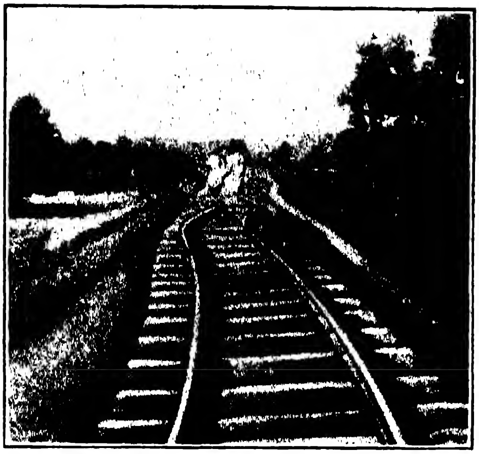

FIG. 8. THE VIBRATION OF THE EARTH DURING AN EARTHQUAKE IN JAPAN THREW A STRAIGHT PIECE OF RAILROAD TRACK OUT OF ALIGNMENT. THESE VIBRATIONS SHAKE TO PIECES POORLY CONSTRUCTED BUILDINGS.

The average rainfall now over land areas is about two and one half feet per year. This means a mile of rainfall in about two thousand years. Some places have much greater rainfall, while others much less. Should the rate of rainfall have been constant during the sedimentary age of one and one half billion years the total rainfall would have been more than one half million miles. This great rainfall has been the ultimate cause of mountain formation and the great changes in the earth's surface. It produces all the force necessary, as it runs from the land to the sea, to lift up new mountains and wear away old ones.

A mountain system, once formed, tends to retain its elevation, as the isostatic adjustment forces subcrustal material under the base of the crust and pushes the eroded blocks up. However, the mountain system will be gradually worn down, for the materials entering at the bottom are denser than those of the eroded matter. If this difference were 15 per cent., then it would be necessary to erode away about seven times the thickness of the material that was above sea level when the mountains were first formed, in order to bring them down to sea level. Thus, to level an uplifted area five thousand feet in elevation it will be necessary to carry away about thirty-five thousand feet of material. We get here the answer to the question of how granite masses, which were formerly below the sediments and even several miles below sea level, can now be thousands of feet in the air as rugged mountain peaks.

During the process of uplift, to restore the isostatic equilibrium disturbed by erosion, there is great distortion of strata with folding, horizontal thrusting, crushing and crumpling, the results of which can be seen in any mountainous area. This wrecking of the strata has been held by many to have been caused by the collapse of the crust as the nucleus shrank away from it, and that all the distortion occurred during the first

FIG. 9. THE CALIFORNIA EARTHQUAKE OF 1906 CAUSED PERMANENT HORIZONTAL MOVEMENTS OF THE GROUND. THE FENCE SHOWN HERE WAS BROKEN AND OFFSET A NUMBER OF FEET. THE HOUSES NEAR BY APPEAR TO HAVE WITHSTOOD THE SHOCK.

FIG. 10. HORIZONTAL AND VERTICAL MOVEMENT OF THE EARTH'S SURFACE NEAR BONDIETH'S RANCH DURING THE EARTHQUAKE OF 1906. HORIZONTAL DISPLACEMENT IS SHOWN BY THE FENCE WHICH HAD BEEN REPAIRED.

uplife. I think the theory outlined above is simpler and more logical than the collapse theory.

Now let us see what is happening where the sediments are deposited in beds ten thousand feet or more in thickness, such as are found at the mouths of great rivers and in plains like those through which flow the Ganges and the Indus rivers in India.

As the material carried by the rivers is deposited, the crust beneath sinks under the load, each part of the crust sinking to regions of higher temperature than that of its original position. But not all the depression is due to the weight of the sediments. As they are lighter in density than the material pushed away from the base of the crust, they would soon pile up so high that the river carrying the sediments would flow off to some other place. Ten, twenty or thirty thousand feet of sediments could not be laid down unless there were an independent contraction of the material of the crust. This contraction would increase the density of the material, and with the lighter sediments would maintain the isostatic balance. Of course during all this process a mass equal to that of the sediments would be pushed away from the base of the crust affected. However, if the sediments were laid down in very deep water, great thicknesses could be deposited without the necessity of having an independent shrinking of the crustal material.

The shrinking of the material of the crust seems to be an after-effect of the rising of the crust under areas subjected to heavy erosion. To restore or to maintain the isostatic equilibrium as the material is eroded away from the surface of a high area, material is brought into the base of the crust below. Each portion affected is carried to regions of lower temperature, and the imaginary surfaces of equal temperature, called geoisotherms, are raised above their usual positions in the crust. In spite of the fact that the wearing down of an elevated region by erosion requires many years, probably millions, the depression of the geoisotherms to their normal positions through cooling probably takes a much longer time. As the material of the crust loses its heat, it undergoes thermal contraction, and probably also a contraction due to molecular changes, thus depressing the surface even below sea level. It seems probable that great geosynclines or troughs in which the rivers deposit their sediments are started in this way. This shrinking continues, even during the early stages of the sedimentation, and thus we have the shrinking or contracting of crustal material under the active sedimentary regions.

The sinking of the crust, under the weight of the thick beds of sediments, will make the material of the crust move to regions of greater heat, thus depressing the geoisotherms, and some time after the sediments have been deposited to a thickness of from ten to thirty thousand feet the material of the crust will become heated many degrees and will expand. This expansion will be partly the usual thermal expansion, such as we see in the mercury of a thermometer, but, in addition, there will be an increase in volume and decrease in density from molecular processes. This expansion

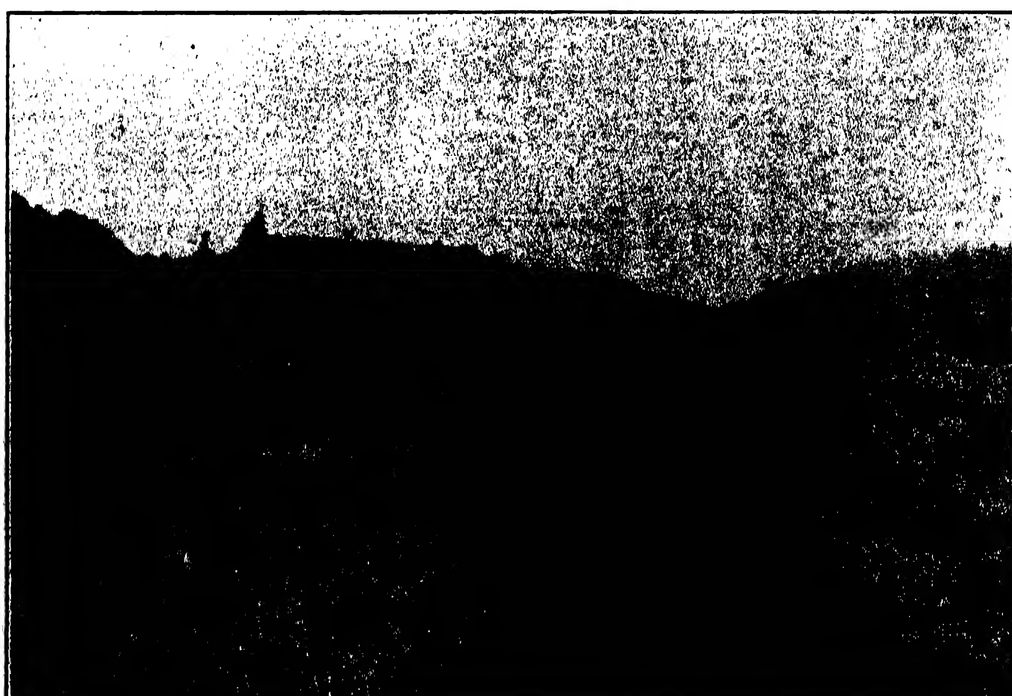

FIG. 11. EARTH MOVEMENT NEAR OLEMA, CALIFORNIA, DURING QUAKE OF 1906.

FIG. 12. FUJIYAMA, THE SACRED MOUNTAIN OF JAPAN, IS AN EXTINCT VOLCANO. TO AGREE WITH ISOSTASY THE LAVA FORMING THE PEAK MUST HAVE ISSUED THROUGH A CRACK IN THE OUTER ROCKS OF THE EARTH. THE MASS OF THIS, AND OF OTHER MOUNTAINS, ARE NOT EXTRA LOADS ON THE BASE OF THE CRUST BENEATH.

will cause the surface of the crust to rise and to form a mountain system or a plateau.

It would appear, from the foregoing, that we have a theory regarding the great upward and downward movements of the earth's surface connected directly with changes in density and in volume. These changes are due to changes in the temperature of the crustal material, as water and gravitation shift loads over the earth's surface. This theory is in harmony with the geodetic and geophysical data resulting from accurate observations.

According to the new theory the principal causes of earthquakes are the sinking of the earth's crust under sediments, the rising of the crust under areas of erosion and the expansion of the crust following great accumulations of sediments. The earthquake is merely a symptom of something more fundamental taking place in the earth's crust. It is the effect rather than the cause, just as we may say that for a human being the chill is a symptom of malaria rather than the disease itself.

They can be predicted as to time and place, but the strength of the quake is uncertain, the element of time is long and the place is large. We may say with some certainty that there will be an earthquake in California during the next week and it is practically certain that it will occur. This statement is based on the fact that there has been, each week during past years, a recorded earthquake shock, or at least one would have been recorded had there been a sufficient number of recording stations, in the state of California. They vary

greatly in intensity. In 1906 an earthquake occurred near San Francisco, causing great destruction of property. Within the last year an earthquake occurred in southern California which caused grat damage. Many earthquakes have occurred which were felt by man, but which caused no material damage. However, by far the greater number of earthquakes have not been felt by human beings but have been recorded on the very delicate instrument called the seismograph.

We may predict that, within the next century, a heavy destructive earthquake is likely to occur along the Atlantic coast. This is a logical deduction from the fact that, in the early part of the last century, there was a destructive earthquake in New England, and in 1886 there was a destructive earthquake in Charleston, South Carolina. We may predict, however, with reasonable certainty of fulfilment that there will be an earthquake on the Atlantic coast within the next five years; this is based on the evidence that many have occurred along the Atlantic coast during recent decades, some of which have been felt but most have only been discovered by the seismograph records.

It also seems to be reasonably certain that we shall have a heavy earthquake sometime in the future in the Mississippi valley, for, in 1811, there was a very destructive earthquake in the vicinity of New Madrid, Mo.

While we may predict an earthquake for a certain general region, it is a very much more difficult matter and may be impossible to make a prediction for a small area such as that covered by a city or even a county. In fact, one would be rather bold who would say that any one city in the United States is likely to have an earthquake of a destructive nature within any given period of years, no matter how great.

With the accumulation of accurate earthquake data the prediction of earthquakes in the future can be made with more accuracy than now.

All great mountain systems have been created by the uplife of vast amounts of sediments. This is the reason why mountain chains skirt the margins of continents and former inland seas. Those are the regions where the thickest deposits are laid down.

Volcanoes are active only along chains of islands and in new mountains in the process of formation. Is it not probable that they are merely incidental to the uplifting of the areas, resulting from the expansion and movements of the material of the crust below?

It seems to be probable that there were no mountains on the earth before water began moving materials from place to place over the surface, but it is probable that the surface had great irregularities. This is a perfectly logical deduction from the results of important investigations made by Dr. Henry S. Washington, of the Geophysical Laboratory of the Carnegie Institution of Washington. He has found that the igneous rocks, usually deep seated but now exposed at the surface, have densities derived from their chemical composition, which bear very definite relations to the elevations of the areas where found. The igneous rocks of the continents are found by him to be lighter than those of oceanic islands. Is it not probable that, before the sedimentary age, the earth's surface was irregular, with the areas underlaid by lighter rocks standing higher than those above denser and heavier rocks? If this is true, then water, falling from the atmosphere to the earth and seeking its level, collected over the heavy areas, thus forming the oceans.

Washington's discoveries enable us to account for the presence of continents

and oceans. It is probable that they maintain their relative positions, although parts of them are affected by uplift and subsidence, due to the transference of eroded material followed by changes in volumetric densities of the crustal material.

What caused the lighter rocks to congregate in some parts of the crust and the heavier rocks in others is one of the great earth mysteries concerning which no one has yet offered a satisfactory explanation.

The geological history of the outer portion of the earth for the last billion and a half years or so is written and recorded in the sedimentary rocks. It is written in a strange language, and many have been the attempts and many the failures to translate it. This is not to be wondered at, for while some chapters remain intact some have been buried from sight, some have been entirely lost and still others are badly torn as a result of the unceasing action of water and gravitation and their consequences. But we are able to make accurately at least a partial translation, by means of the alphabet furnished by the geodetic, geophysical and geochemical data collected in recent years.

WHY WE SHOULD BE MORE INTERESTED IN NUTRITION

By Professor VICTOR E. LEVINE
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THE age in which we live marks the beginning of many departures from the past. It is an age in which more and more attention is being focused upon the individual human being. Civilization is entering upon a period of humanization. This tendency is well marked in many lines of endeavor, but it is especially to be noted in science. Heretofore science concerned itself mainly with branches more or less of an impersonal nature, as astronomy, geology and mathematics. Even chemistry and physics occupied the attention of the chemist and the physicist for the sake of these sciences alone. It was a period of science for the sake of science, and there was a marked differentiation in so-called pure science and in applied science. To-day even pure science is turning sharply its worthwhile efforts in the direction of applications mankind can make from its marvelous findings.

We are beginning to realize that the proper study of mankind is the human being, just as in biology the study of the cell is regarded as the key to the knowledge of the workings of the complex biologic organism. There is more or less a feeling that all useless science is an empty boast. The tendency toward the direct application of science to the problems and to the welfare of the human being constitutes, indeed, a great advance in our mode of thinking. It is this change in viewpoint, the directing of our efforts toward the betterment of the individual, toward the development of a higher type of human being that has brought forth great progress in such sciences as anthropology, sociology, economics, psychology and also preventive medicine, which concerns itself with the health of individuals, of communities and of nations. The greatest scientific achievement of the age is not the automobile or the photoplay or the aeroplane or even the radio. It is the saving, thanks to the progress of preventive medicine, of the lives of millions of our most precious possessions—our children.

When men of science turned their guns upon the individual they were much surprised to find that they lacked even the elementary knowledge of some of the most essential things that concerned him and the things nearest him. They realized but too well that in the past they looked for gold in fields far away and that the advice of Socrates, "Know thyself," was more honored in words than in actual observance. The lack of knowledge was very apparent in reference to nutrition, that is, in reference to the science of food and feeding. Experts in this particular field of public health were much surprised themselves to find that most of our knowledge relative to nutrition was more or less handed down to us in a traditional way and that a good deal of that knowledge was fundamentally wrong, being based upon opinion, which experimental facts and the experience of the race could not justify.

Nutrition is becoming more and more recognized as one the most fundamental factors in the problem of private and

public health. We are fully aware that man does not live by bread alone and that he does not live in order to eat; but at the same time we must realize that our bodies are what we put into them and that a great many ills, both minor and major, depend upon some dietary indiscretion or some dietary insufficiency. These we shall discuss at some later date.

Not only scientists and welfare workers, but even poets recognize the importance of nutrition. Take Byron, for example, who, in his poem "Don Juan," proclaims:

All human history attests
That happiness for man—the hungry sinner,
Since Eve ate apples, much depends on dinner.

Nor is Byron the only poet who realizes the value of nutrition. Owen Meredith, although a little gloomy about friendship and poetry and music and art, places cooking and dining upon quite a high pedestal. Hear his words:

We may live without poetry, music and art;
We may live without conscience, and live without heart;
We may live without friends, we may live without books;
But civilized man can not live without cooks.

He may live without books—what is knowledge but grieving?
He may live without hope—what is hope but deceiving?
He may live without love—what is passion but pining?
But where is the man that can live without dining?

Is Instinct a Safe Guide to Nutrition?

We have just pointed out the fact that modern scientific research has for its ulterior and highest motive the improvement of the race through the individual human being. Heretofore civilization focused its efforts upon building through the development of institutions. The individual as such was not concerned in the plan. That this type of civilization has much in it to be regretted is best expressed in the language of Edwin Markham, the Abraham Lincoln of American poetry:

We are all blind until we see
That, in the human plan
Nothing is worth the making, if
It does not make the man;
Why build these cities glorious
If man unbuilded goes?
In vain we build the world unless
The builder also grows.

This turning of the limelight upon the human being as the important building stone of society has resulted in remarkable progress and new viewpoints in the subjects concerning him, such as psychology, sociology and public health or hygiene, of which nutrition is a part.

There was a time when nobody even thought in terms of health. Pain or fear drove many a person to the nearest physician for relief. He became a patient and there ended his responsibility. Modern humanized science has made us realize the extreme value of the age-old, half-accepted, half-rejected idea that an ounce of prevention is better than a pound of cure.

Many of us will ask the question, Why worry about nutrition at all? Does not instinct guide us through appetite into proper choice of food? So do many of us believe. But one of the misconceptions that is dying a slow death involves the relation of instinct to the proper choice of food. Some contend that it is not necessary to worry about our nutritional requirements, since the good angel, instinct, is ever on guard duty to protect us. This idea does not hold up under actual experimentation and observation. Modern nutrition demonstrates clearly, especially in reference to the human being, that instinct is not a safeguard to proper feeding. Modern science has taught us that while instinct preserves us from a great many pitfalls,

it surely does not prevent us from loading our systems with foods improper for growth or for maintenance of health and vigor. A quotation from a poem will bear out this point in a rather humorous way:

> 'Tis not her coldness, father,
> That chills my laboring breast,
> It's that confounded cucumber
> I've ate and can't digest.

One of the greatest advances in modern nutrition lies in a realization of the fact that instinct or appetite is not a guide to proper feeding. Often it is taste; most often it is habit. As for taste, the professional cook can so pepper and salt and season an ancient steak as to give it the appearance and flavor of youth. How often do you read in the daily newspaper of people dying of food poisoning resulting from a carefully prepared meal of which they partook at some social dinner or in some very beautiful dining room of a modern hotel!

In the ages beyond history we find the Neanderthal man of some fifty thousand years ago, the reindeer man of some thirty to fifteen thousand and the Neolithic man of some ten thousand years back. These ancient sires no doubt relied completely on instinct for preservation of self and race. Through the thousands of years, into the biblical days and way up to the threshold of the industrial revolution, only some one hundred years ago, man practically led the same life and ate the same way. During these long years human intellect was in the process of development. Mind, indeed, made progress, but it was at the great expense of instinct. Among other things man lost his keen sense of smell, vision and hearing. When the industrial revolution began to make itself felt in relation to food supply, the human being had lost his instinct for the selection of natural food, and he began, without question or doubt, to make use of foods industrialized, commercialized; demineralized, devitaminized, devitalized; colored, bleached, dyed; smoked, heated, boiled, cooked, fried; polished, extracted, concentrated, distilled; preserved, pickled, canned, refrigerated.

Strange to say, not instinct but habit is the most important factor in appetite. We like the foods which we have been accustomed to from early years. We rave about the kind that mother used to make. The Irish like their potatoes; the Jews, their gefüllte fish; the Italians, their macaroni; the Scotch, their oatmeal; Mexicans, their chili con carne; the Japanese, their rice cakes. In the southern states people like bread made of cornmeal. Those who grow up on cornbread learn to like it. During the great war the French people could not accustom themselves to eat corn even under the pressure of lack of food.

The first woman who secretly introduced to her neighbors the delights of sauerkraut and dill pickles and the person who invented the "hot dog" were indeed individuals of no mean courage. The first man who ate eels was looked upon with considerable suspicion. Had neurological institutions existed at the time, he would no doubt have been held for further observation. The first man who swallowed an oyster performed as great a feat as the most daring vaudeville acrobat.

Some people find certain kinds of cheese outside the pale of polite society, though other folks rave about them. As a matter of fact it requires special training, not of stomach but of mind, to be able to eat certain dairy preparations labelled "cheese." Wines Spaniards care for are not palatable to Italians, and the wines of the Italian strike horror to the polite taste of the Spaniard. Beer is drunk everywhere in Europe, and in America whenever and wherever it is obtainable. When it was first introduced into Italy from Germany, many Italians found themselves unable

to comprehend how any one could drink it and at the same time pretend it was pleasant. The question at one time arose in Rome whether it was permissible to take beer on fast days. The cardinals who tasted it proclaimed that not only did it seem permissible but that it was a mortification to drink it, and that it was therefore a proper Lenten exercise.

Personal habit dictates our likes and dislikes with reference to food. Eating too little or too much is also a matter of habit. It is true that some people have an idiosyncrasy towards certain foods. We will soon speak of idiosyncrasy as food allergy. But by far the greatest number of food dislikes are based entirely upon subjective feelings, which can be overcome by habit and training. Some people have a natural repugnance for a very nutritious article of food, like eggs. That this feeling is subjective is evident from the fact that the laity have many opinions about the egg. Some say it makes them bilious, whatever that means. Some say it is too heavy for them; some find it distinctly constipating. Others claim that it has a marked tendency to develop diarrhea. Yet people who come into a tubercular sanitorium with an unreasonable disinclination for eggs soon learn to like them to the extent of taking a half a dozen or more daily.

Custom is also responsible for a great many dietary peculiarities. In some places the kidney and the liver are eaten with relish. The French like brains and other special parts. What are dainties to some people are repulsive to others. The Anglo-Saxons, as a rule, stick to muscle cuts of meat. McCollum has shown that this type of animal food is, however, by no means as nutritious as the organs like the liver, spleen, lung and other internal parts. But as a rule they are not used, for we lack the accustomedness to them. To the great majority of mankind the idea of eating horseflesh is repulsive, yet numbers of people in various parts of Europe have conquered the initial repugnance and are finding this animal food quite as pleasant as cow's meat. Snail soup is relished in Italy, while down at Marseilles gourmands feast on angle worms and find them appetizing.

The Chinese and Japanese prefer rice to wheat as a food grain. They seem to like polished rice even better than unpolished rice. We know that polished rice is injurious to health. Instinct should have demanded unpolished rice, since the polished grain leads to a very fatal disease called beri-beri.

We all know that carbohydrates, that is, sugars and starches, are very important in our diet. Lack of carbohydrate in the diet leads to serious disturbances, which may even result in death. The Eskimo diet is very rich in protein foods and fat and is extremely poor in sugar and may entirely lack starch. Yet it is surprising to learn that sugar is much disliked by Eskimos and that it takes a long time before they get used to it. We consume far too much salt in our diet. The Eskimo, on the other hand, gets just enough salt from his food without having recourse to the use of table salt. Yet the Eskimo gets used to salt more quickly than to sugar.

To show you the importance of habit again, we wish to mention that Eskimo dogs brought up on seal meat would have no other meat, even though they may be suffering from extreme hunger. In our laboratory we have often seen albino rats refuse food for days or eat very little of a new dietary mixture equally as adequate as the one to which they have been accustomed. Europeans who have never eaten bananas or tomatoes find them tasteless and disagreeable. It takes some time before they get up any enthusiasm for the tomato in spite of the fact that it is a very superior food, being rich in three important nutri-

tional ingredients—iron, vitamins and roughage. Next to the orange the tomato juice ranks in importance as a preventive of a disease of childhood and of adult life known as scurvy.

From what has been said it seems imperative for us not to overlook the importance of habit in medical treatment. Abrupt change in diet does not seem to go well with many people. Lack of appetite and even serious gastro-intestinal upsets arise. Individuals away from home often find themselves in constipation or in diarrhea for some time before they get accustomed to a new dietary régime. Perhaps this preliminary mal-adjustment is mental or it is the result of a disturbance in the physiological rhythm of the gastro-intestinal mechanism. This disturbance may be in the nature of a very slight allergic shock, which disappears as soon as the stage of desensitization is reached. In the treatment of many chronic conditions, such as those involving gastro-intestinal, cardiac or renal derangement or in diabetes, better results may be obtained in some cases or in many cases by making gradational the changes in diet necessary to approximate it to the contingencies of the given pathological condition.

That appetite is not a safe guide to the body's need is seen from the fact that many people eat too much protein or use too much carbohydrate. Modern medicine teaches us that excessive protein as is found in such food as meat may lead to a deterioration of the kidney and may result in derangement of its functions, giving rise to nephritis. Modern medicine also teaches us that excessive use of sugars and starches may so overwork one of the organs, the pancreas, that diabetes may be the outcome.

That appetite is not an index to the body's need for food is again seen in the prevalence of fat persons. Certain types of overweight are due to excessive food intake. The statistics of life insurance companies and the experience of physicians indicate that obesity is not an asset but a liability. Overly fat people have a much smaller chance in pneumonia or in heart disease than persons of normal weight.

Some people are very susceptible to certain kinds of foods. They suffer as a result of this susceptibility from gastro-intestinal upsets, from asthma, from skin outbreaks, such as eczema or urticaria, popularly called hives. This susceptibility is referred to as food allergy. Such innocent and simple foods as eggs, milk, beef, pork, beans, onions, cabbage, rice, tomatoes, strawberries, honey and others have been found to be the underlying cause of asthma, acute abdominal pain or skin outbreaks. Often the patient is aware of an allergic attack after eating certain foods and keeps away from these as a result of experience. Most often it is the physician who diagnoses the case by means of history or special skin tests and advises the patient to avoid the food responsible for this condition.

Still another example as to lack of relation between instinct and biological need we will take from the experience of mothers. It is a very easy matter to explain to a mother how a child should be fed in order to insure normal growth and development. It is not a difficult matter to convince mothers that these foods are needed, nor to arouse in them an interest and a desire to have their children living on such an adequate diet. But it is by no means assured that the child will be so fed. Here we may meet with a stone wall of children's likes and dislikes and mother's inability to alter them. You hear these expressions from mothers: "My child does not like milk. I can't make him eat. He hates the sight of vegetables." Many mothers already know what a child should be fed, but the all-absorbing question is, "How can I get him to eat it?"

The inability of instinct to serve as a guide also holds true for animals. We shall cite from some experiences of Professor Elmer V. McCollum, of Johns Hopkins. Young white rats grow well on a mixture of fifty parts corn meal, thirty parts alfalfa-leaf flour and twenty parts cooked beans. These may be ground together so finely that they must be eaten in the proportions given above. McCollum offered to growing white rats corn, alfalfa and cooked beans in separate dishes. They liked the taste of the corn better than the other two foods. They tried to live on corn alone, which in itself is not a very superior food, with the result that they grew less rapidly than the animals fed proper mixtures, were not so healthy, and did not possess the same degree of vitality.

To prove again that instinct does not always come to our defense in case of food we will cite another little anecdote. Charles Lamb, returning from a jolly dinner party, took his seat in a crowded omnibus. Shortly after, a portly gentleman put his head in and asked, "All full inside?" Lamb, who was nearest the inquirer, said, "I can't speak for the remainder of the company, sir, but as for myself, that last piece of oyster pie did the business for me."

Since the cues coming from our natural desires are misleading, we are impelled to seek through the experimental method information as to what constitutes adequate nutritional needs. Instinct will not guide us; food faddists mislead us; politicians and legislators do not understand, are indifferent to questions of public health or are engaged in the profitable pastime of vamping votes for an impending election. Our channel of knowledge is the scientist of the laboratory with his rats and his guinea pigs, the public health worker, the dietitian and the progressive, open-minded clinician at the bedside.

We must study food and food values and proper diet just as we must study history and geography, chemistry or mathematics. Since we can not rely upon instinct we are compelled to be seekers of knowledge in the field of nutrition.

As the problems of nutrition become better understood and more fully appreciated, the science will assume increasingly greater importance in the prevention and cure of disease, and consequently in the hygienic, social and economic uplift. From time immemorial nutrition has played a very prominent though unrecognized part in the story of man. Even in biblical beginnings, food seemed to be closely bound up with his physical and spiritual well-being. The records have it that it was woman who induced him to eat; he took to drinking of his own accord.

INFANT MORTALITY AND SURVIVAL OF THE FITTEST

By Dr. CHARLES HERRMAN

NEW YORK

THERE are two seemingly opposed views with regard to the advisability of reducing the infant mortality. One view is stated by Popenoe and Johnson as follows:

> Part of the children born in any district in a given year are doomed by heredity to an early death; if they die in the first year, they will not be alive to die in the succeeding year and vice versa. . . . If the gain is by great exertions made more than temporary; if the baby who would otherwise have died in the first months is brought to adult life and reproduction, it means in many cases the desemination of another strain of weak heredity, which natural selection would have cut off ruthlessly in the interest of race betterment. Insofar, then, as the infant mortality movement is not futile, it is, from a strict biological viewpoint, often detrimental to the future of the race.

Pearson, Snow and Ploetz have demonstrated by refined statistical methods that "a selective death-rate is strongly operative in man in the early years of life." The other view, which is held by Newsholme, Yule and others, is that "a high infant death-rate in a given community implies a general high death-rate in the next few years of life; while low death-rates at both age periods are similarly associated." . . . "There is a very high correlation between the amount of infant mortality and of mortality at ages one to five." Speaking of conditions in New York City, Dr. S. Josephine Baker says:

> One of the great objections that has been raised against any intensive child welfare work has been that it perpetuates the unfit. In order to meet this objection we have kept rather careful statistics in New York City with regard to the child after it has passed the age of one year. Five years after we began our work with babies, we began to watch the effect on the mortality of children under five years of age. We have found since that time that the mortality in this age group, under five years, has shown a decline that has been much greater than that in the group under one year of age. In other words, the children are not only alive and well at the end of their first year, but they continue in good health throughout child life.

There is nothing in this statement which is incompatible with the conclusion that natural selection is operative in the early years of childhood. Almost all the reduction in mortality has been due to improvement in the care and feeding of infants and young children. These factors are operative not only in children under one year but throughout childhood. As selection is more strongly operative during the first year, these factors would have a greater effect during the succeeding years. Pearson and Snow have had such a large experience in the handling of statistical matter that their conclusions can be accepted without hesitation. These two seemingly opposed views are in reality not incompatible. There are two distinct groups of causes of infant mortality: the one depends on the character of the germ plasm; the other is not primarily dependent on the germ plasm, but is accidental and therefore to a great extent preventable. To give an example: anencephaly is due to a defect in the germ plasm; death from cerebral hemorrhage in a newborn following a difficult labor, and possibly lack of skill on the part of the attending obstetrician is accidental and preventable. There are also some

deaths which are due to a combination of both causes. If a baby contracts an infectious diarrhoea as a result of drinking contaminated milk, whether it dies or succeeds in overcoming the infection will depend largely on its resistance; in other words, on the character of the stock.

Those who claim that the reduction of the infant mortality is not an unmixed blessing have in mind primarily the saving of infants who have defects in the germ plasm; those who hold that the results obtained by the infant welfare campaign are entirely beneficial are referring to the deaths which are primarily accidental and due to preventable causes. The dictum that "a high infant mortality results in the sacrifice of the unfortunate, not the unfit" should read, "a high infant mortality results in the sacrifice of the unfortunate *as well* as the unfit." It is sometimes said that some of our greatest men were weak and sickly infants and would have been lost to humanity if the eugenist had his way. Goethe and Newton are favorite examples. In his autobiography Goethe says, "These good aspects which the astrologers managed subsequently to reckon very auspicious for me may have been the causes of my preservation; for *through the unskillfulness of the midwife* I came into the world as dead and only after various efforts was I enabled to see the light." There is here no indication of a defect in the germ plasm; on the contrary Goethe fully appreciated the importance of descent from good stock, for he says in his well-known couplet that he obtained his good stature, his energy and earnestness from his father, and his lively disposition and imagination from his mother.

Natural selection is still potent. Of the neonatal deaths, approximately 75 per cent. are due to malformations and so-called congenital debility and are largely beyond our control. As will be seen by referring to the chart there has been little or no reduction in this group. In other words, the reduction has been for the most part in the group of causes not primarily of germinal origin. At the present time, in spite of all our efforts, the defective embryos do not reach maturity, or if they do mature, they die shortly after birth. We can not accept the statements that "a *few* causes of stillbirth depend on factors relating to the child itself," and "sixty-five per cent. of the deaths from congenital diseases under one month are preventable by means of prenatal care." Adequate prenatal care and improved obstetrics will markedly reduce the neonatal deaths due to syphilis, to the toxemias of pregnancy, to the accidents of labor; but there will still remain a large number due to defects in the germ plasma, which no amount of prenatal care, *as now carried out*, will prevent. It is possible that in the future we may be able to influence the character of the germ plasm during pregnancy; but at present the health of the newborn infant and the ability of the mother to nurse depend more on her health *before* than during pregnancy. Natural selection is operative in infancy and childhood. All children must pass through a series of severe tests. One is reminded of the cross-country-run of college boys. The contestants must overcome a variety of obstacles; they must struggle through thick brush; ford streams; climb over fences and crawl under nets. Only the sturdier reach the goal. About 15 per cent. of the fertilized ova perish; of those that mature about 5 per cent. result in still-births. Some must pass through the dangers of a difficult labor; later some find it difficult to cope with the hazards of artificial feeding and the heat of summer; so that by the end of the first year from 7 to 10 per cent. have succumbed. Still later they must overcome the infectious diseases of child-

hood, measles, whooping cough, diphtheria and scarlet fever, with their frequent complications. It has been estimated that not more than 60 per cent. reach adult life and leave offspring. Thus the least fit from a physical and immunologic standpoint are eliminated.

Among uncivilized tribes, as among animals in a state of nature, natural selection has full sway; the weak and deformed are killed or allowed to die; exposure or lack of food in times of famine or when migrating from place to place kills some of those who are fortunate enough to survive the first few years; disease does the rest; so that only the strongest reach maturity. In modern life, especially in our large cities, selection is still operative, but its methods are somewhat different. The weak are protected against the rigors of climate, provided with proper food and given the tenderest care; but the character of modern life produces more miscarriages, premature infants and stillbirths. More infants must be artificially fed, and still more important in our densely populated cities, there is much crowding, and as the communicable diseases are always present, contact infection is easy. The result is that practically all infants and young children contract these diseases sooner or later, and the most unfit from a *physical and immunologic standpoint* are eliminated. This is shown by the fact that there has been comparatively little reduction in the mortality from respiratory and infectious diseases. In connection with this discussion the following passage from Boswell's Johnson will be found interesting:

Boswell: "I believe, Sir, a great many of the children born in London die early."

Johnson: "Why, yes, Sir."

B.: "But those who do live are as stout and strong people as any. Dr. Price says they must be naturally strong to get through."

J.: "That is system, Sir. A great traveller observes, that it is said there are no weak or deformed people among the Indians; but he with much sagacity assigns the reason for this, which is, that the hardships of their life, as hunters and fishers, does not allow weak or diseased children to grow up. Now had I been an Indian I must have died early; my eyes would not have served me to get food. I must have starved or they would have knocked me on the head when they saw I could do nothing."

B.: "Perhaps they would have taken care of you. We are told that they are fond of oratory. You would have talked to them."

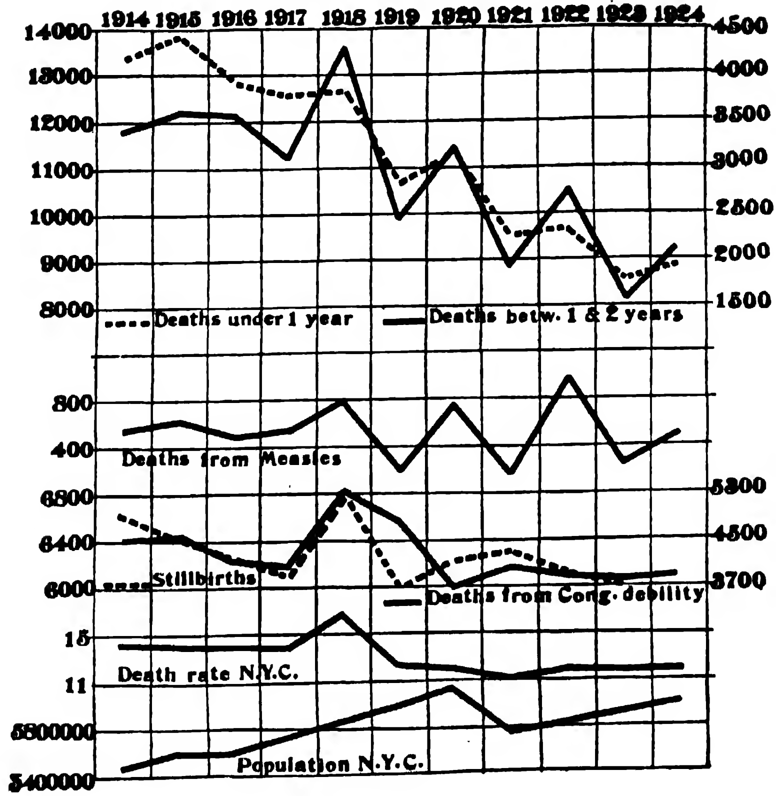
J.: "Nay, Sir, I should not have lived long enough to be fit to talk. I should have died before I was ten years old. Depend upon it, Sir, a savage when he is hungry will not carry about with him a looby of nine years old, who can not help himself. They have no affection, Sir."

B.: "I believe natural affection of which we hear so much is very small."

J.: "Sir, natural affection is nothing; but affection from principle and established duty is sometimes wonderfully strong."

Referring to the chart, certain features of the graphs will be noted, which suggest the action of natural selection. The population of New York City has increased only 9 per cent. during the last ten years, due principally to the absence of immigration during the European war and the restricted immigration since then. The number of births has decreased about 7 per cent. during this time, due principally to the well-known fact that the birth-rate is higher among parents of foreign birth. I have therefore found it simpler to use the number of deaths rather than death-rates. The death-rate between one and two years of age is estimated from the probable total population, so that it would not be more reliable. It will be noted that there has been a remarkable reduction in the number of deaths under one year and between one and two years of age; that when the mortality under one year is high in one year, it is low in children between one and two years of age in the succeeding year, and *vice versa*. This at least suggests the action of natural selection. In New York City measles is always present, and a very large percent-

NEW YORK CITY



age of all children contract the disease during the first five years of life. Almost all the deaths from this disease occur in children under five years, so that it serves as a very fair test of the resistance and the immunologic reaction of children. If we compare the deaths between one and two years of age with the deaths from measles we find a striking parallelism. This is not true of the other communicable diseases of childhood. The parallelism is not quite so striking under one year, because infants under five months are relatively immune to measles, and from five to eight months the disease is usually of a mild type; it is therefore only during the last four months of the first year that the disease is likely to be of a severe type, so that death results. Almost all the deaths are due to a complicating pneumonia, which kills those who are physically and immunologically below par. The year 1918 shows the selective action of the severe epidemic of influenza.

As there has been a decrease of 7 per cent. in the total number of births per year, we see that there has been no reduction in the number of still-births, or the deaths due to malformations and congenital debility. In other words, selection still eliminates those with defects in the germ plasm and those of low vitality. The reduction in mortality has been chiefly in deaths due to gastro-intestinal diseases, because here the chief causes, imperfect milk supply and ignorance in the care and feeding of infants, could be removed. There has been but little reduction in the deaths from in-

fectious diseases (except diphtheria) and respiratory diseases because the causative factors have been largely beyond our control.

Conclusions

The two seemingly opposed views with regard to the advisability of reducing the infant mortality are not incompatible. There are two distinct groups of causes of deaths in infants; the one group is due to defects in the germ plasm and destroys the weak; the other is largely accidental, affects the strong as well as the weak and is to a great extent preventable. The reduction in infant mortality has been almost entirely in the latter group. A high infant mortality sacrifices the unfortunate *as well* as the unfit. Natural selection is still operative. There has been no reduction in the number of miscarriages, stillbirths or deaths due to congenital debility. There has been very little reduction in deaths in infants due to infectious and respiratory diseases because these have been largely beyond our control. The health of the infant and the ability of the mother to nurse it depend more on the health of the mother before than during pregnancy. From the moment of conception children are subjected to a series of severe tests; only about sixty per cent. succeed in passing all these tests, reach adult life and leave offspring. In large cities with a congested population the infectious diseases, particularly those which attack the respiratory tract, are chiefly instrumental in eliminating the physically and immunologically unfit. Until we discover methods of influencing the germ plasm and immunizing against the infectious diseases, we shall not radically interfere with the operation of natural selection. By that time we shall probably have an intelligent appreciation of the importance of complete segregation of the unfit or possibly we shall have Haldane's ectogenetic mothers.

MIXING THE ISSUE IN IMMIGRATION

By Professor EZRA BOWEN
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PURELY qualitative changes in the affected populations are the most important result of immigration and emigration. Matter for deep concern, these inter-territorial human seepages, but thought trained upon their quantitative bearing is largely wasted, though all superficial evidence shouts, No—and arresting work has been carried through on that hallucinatory ground.

Between the sidewalk and the curb, in front of your house, there is a little plot of ground; overflowing foot traffic and a summer drouth have made it almost bare; a tuft or two in the most favored regions comprise the entire grass population. To improve matters, you throw a wire guard around it; you water faithfully, and add perhaps some grass food (fertilizer) to the earth. Weeks pass; and the original grass population has spread to the limits of the plot.

Instead of looking to the offspring of the original population to take up unoccupied regions, you might have sown strange seed—brought in the offspring of another plot, another land. In either case, the result is one—the choice has at least no quantitative bearing, though it will of course affect the breed. Had all immigration been cut off in 1850, the population of the United States would be, in number, exactly what it is;[1] this ancient contention now has marshalled behind it hosts of biologic and economic evidence. If an amelioration in living conditions warrants, population will increase and take up the slack. That this growth comes from immigration, increased birth-rate or decreased death-rate matters not; the quantitative result is in any case the same, and entirely the effect of more latitude in the conditions to existence.[2]

Short, sharp waves of immigration and emigration have important transitory by-products in unemployment, labor shortage and other discrepancies that are almost purely quantitative matters; but the main long-time currents of migration, which give the problem its constant features, produce almost purely qualitative changes. Let us instance a grouping of facts that brings into sharp relief qualitative changes resulting from migration:

PERCENTAGE OF POPULATION IN AGE GROUPS[3]

[3] E. R. A. Seligman, "Principles of Economics," tenth ed., 1924, p. 56.

	1–15 years of age	15–65 years of age	65 years or more
United States	31.10	64.87	4.03
Massachusetts ...	27.10	67.88	5.02
South Carolina ...	41.60	55.50	5.90

[1] F. A. Walker, *Forum*, August, 1891. (The biologic principles involved are expressed best by E. M. East and R. Pearl in America and by J. B. S. Haldane and J. Swinburne in England. Whatever modification must be made, when we come to the human case in population, on account of the differential living-standard, is easily exaggerated. The standard of living of that purest of American strains, in the mountains of our southern states, reported by Professor Ross [cited below] is as low as that of any foreign-language group—and who, working in such groups, has not found that the assumption of the American living-standard by the newly admitted immigrant is frequently but a matter of months?)

[2] E. M. East, "Mankind at the Crossroads," 1923, Chapter IV.

Make the center column the focal point of attention; then compare the second and third items with the first. In Massachusetts, persons of wealth-producing age are in abnormally high proportion: wealth-producing individuals form a much smaller proportion of South Carolina's population. Forty-five per cent. (persons too old or too young for economic activity) must, in South Carolina, ride upon the backs of the other fifty-five; but in Massachusetts the earners—sixty-eight per cent. of all—need support only thirty-two per cent. Many matters must be brought to bear in explaining the great wealth of Massachusetts and the comparative poverty of South Carolina—but the effect of migration is beyond a doubt one of them. Thousands of able-bodied young men, native whites, have left South Carolina's worked-out farms and timber regions; and thousands of able-bodied, young Europeans have swarmed into Massachusetts' mill towns. Many items must be taken into account in explaining the great wealth of the United States and the comparative poverty of Europe; but the economic blood of Europe has been losing steadily its red corpuscles, and the United States has gained them by transfusion.

Had restriction of immigration come fifty years ago, the population of the United States would be in number exactly what it is: had there been no emigration, the population of Europe would be no larger and no smaller than at present.[4] Migrations have no constant quantitative bearing. But immigration has kept the economic blood count of the United States well up; while in like degree the economic body of Europe has suffered from anemia—a momentous, wholly qualitative, matter.

An important genetic principle has a bearing here: The mixed breed is stronger, better able to cope with life, than the pure.[5] Who has not had a disastrous experience with one of those neurotic, inbred, Boston bull-terriers—his neighbor's or his own—tight little bundle of muscle and nerve with mottled-brown, twitching skin? In winter he is in the conservatory, the cat without; he races madly up and down, barking, whining and leaping against the pane, gaining nothing and finally becoming violently ill. In August his nerves blow up completely; he just misses inflicting probable death upon a neighbor's child, and the long arm of the law whisks him into the nothingness from whence he came. How different the common campus dog! Chest of a bull, lean clean legs, scent of a hound, his digestion is never disaffected, though his most regular diet be of grimy bits of half-soaked pretzel and an occasional boiled-out soup bone. Taking kicks and caresses philosophically, he is always serene. Just so with human beings: the mixed breed meets the bluff and guff of each new day more adequately than the pure. There is no such thing, of course, as a really pure human breed[6]—forever the waters have been mixing[7]—still, there have always been back-eddies where a small population swirls round and round, mingling only with itself, taking on a flavor uniquely its own. America has such back-eddies. In the present writer's county, Northampton, of Pennsylvania, lives a master carpenter whose family immigrated in 1641. Speaking English fatigues this man—German is the language of his recreating hours. Then there are those sinkholes of humanity in the mountains of Kentucky, North

[4] E. B. Reuter, "Population Problems," 1923, p. 195.

[5] E. Huntington, "The Character of Races," 1924, pp. 18, 19.

[6] E. Huntington, "The Character of Races," 1924, pp. 18, 19.

[7] J. A. Thompson, "Outline of Science," 1922, p. 1099.

Carolina, Tennessee[8] and in the pines of Southern New Jersey. Broader, of course, and less aggravated, still Europe is made up almost entirely of such whirlpools as these. There has been immigration and emigration from one European country to another; but here again America with her constant influx of new blood has had, for three hundred years, a great advantage—another far-reaching and purely qualitative bearing of migration.

But too much, or too rapid, mixing is also bad.[9] The skew faces and grotesque figures, common in every seaboard mill-town, are expressions of this principle.[10] Skew faces and grotesque figures, furthermore, may well be the outward and visible signs of an inward and spiritual distortion; for it is not quite clear whether thinking is done only in one specialized spot, the brain, or in every part of the body.[11]

Too rapid mixing means grotesque bodies, and there is apparent evidence for believing that this in turn indicates misshapen minds, distorted spirits. Moreover, man's anatomical integrity may be his most important asset. Of gorillas, 55 per cent. have seventeen spinal vertebrae; almost as large a proportion (40 per cent.) have sixteen; and 5 per cent. possess but fifteen. Man's structural integrity is far greater: ninety-six out of every hundred have seventeen spinal vertebrae; only a scattered few have eighteen; other counts are almost unknown.[12] Man is the animal of greatest integrity, the conserving animal—and this stability does not stop, of course, with vertebrae. Anatomical integrity is a tremendous human asset; one not to be squandered in too rapid mixing.[13] Here, America has had, in her flooding immigration, a very messy matter thrust between her hands.

A quickening of the currents of migration by the repercussions of a world war is everywhere in evidence. America has enacted under a mask of numerical quotas what is in form a quantitative, but in effect a qualitative immigration-restriction measure; the center of European emigration to the United States has been shifted sharply northward and westward. But the political impetus that put this bill through Congress sprang from a quantitative consideration: the labor vote wanted American jobs protected from an imminent influx of European jobfillers.[14] South American countries on the other hand encourage immigration to make good their labor shortages.[15] To fill their armies, European countries discourage emigration. Everywhere, quantitative considerations are uppermost and ruling. But this absorbing human question, this problem of migration, has been gripped wrong end to. Immigration and emigration, except for short sharp ebbs and flows, have no quantitative bearing; the problem they present is mainly one of qualities.

[8] E. A. Ross, *The New Republic*, January 9, 1924.

[9] J. A. Thompson, "Outline of Science," 1922, p. 1,000.

[10] E. A. Ross, *The New Republic*, January 9, 1924.

[11] H. C. King, "Rational Living," 1919. Chs. IV, V, VI, VII, VIII.

[12] T. W. Todd, THE SCIENTIFIC MONTHLY, December, 1924.

[13] E. G. Conklin, quoted in J. A. Thompson's "Outline of Science," 1922, p. 1,094.

[14] It is quite true that, during its pendency, intelligent discussion of this act centered upon its qualitative bearing, but intelligent discussion was not the force that carried it through Congress.

[15] William A. Reid, THE SCIENTIFIC MONTHLY, March, 1925.

THE SEARCH FOR THE MASTER KEY OF THE UNIVERSE

By Dr. DAVID STARR JORDAN
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A MASTER key opens all locks and solves all problems. Recent advances in knowledge have raised the question among certain scientific men as to which branch of research will first give us the master key to the universe. Shall we find it in astronomy or in physics?[1] Does the clue to infinity lie with the inconceivably great or in the impalpably small?

The astronomer points to the heavens crowded with stars, their visible number increasing a hundred fold after each improvement in the telescope. Through instruments and methods of precision, one of the most helpful of the latter being mathematics, we have learned that each luminous point is a mighty sun, blazing in illimitable distances, its light taking thousands on thousands of years to reach us across the cold, empty, intervening space. We have also found out how far away a few of the nearest are, and of these one can measure the size, even to a million times the substance of our sun. We can furthermore analyze their chemical composition and discover what degree of heat they radiate—some at least thrice that of our sun. We can guess, but probably never find out with certainty, whether living organisms exist on any of the non-luminous planets which may (unknown to us) revolve around them. Nor can we be sure whether our planets or any others have been thrown off from a central orb, or whether, on the contrary, a sun has picked them up in their whirl through space, as the earth picks up meteorites. Nor do we know whether this our solar system is cooling off, running down like a wound-up watch to end in cold stagnation. Nor are we sure that we are not still in progress of heating-up for more cosmic adventures.

The better aided our vision, the more stars we see. Is there any end to the mighty series at the center of which our earth seems to us to stand? Probably, indeed, no other point has a better claim, for infinity has neither center nor circumference. One can not even conceive of an end to space, or a limitation in the number of stars space may contain; nor can we, on the other hand, conceive of its having no limit. All that we know may be included in infinity, yet forming no fraction of it, because a fraction means limitation of the whole. Neither is the problem eased by the unscientific presumption that the universe itself may be a sphere, and that all outward motion, actual or fancied, in its range would be like a line on the earth which, if pushed far enough, returns on itself. An ant travelling over the surface of a globe has been suggested as an illustration of this hypothesis.

A like paradox appears in the case of time: "Time is as long as space is wide." By this declaration Professor Hutton, of Edinburgh, startled the Scottish theologians of the eighteenth century. Space

[1] For an illuminating discussion of this problem, see Dr. Paul R. Heyl, in THE SCIENTIFIC MONTHLY for July, 1924.

had steadily widened on their hands, but they clung to the idea of a wicked and short-lived world, "a sink of iniquity," created not long ago and soon to pass away "in planetary combustion." Hutton, however, saw in its structure "no trace of a beginning: no prospect of an end." As a matter of fact, inspection of the geologic configuration of our globe plainly shows that its hard crust was inconceivably old, hoary with age, before life of any kind appeared on it.

What then of the sequences we call time? What happened one year or a hundred years before time began? What will happen a year or a hundred years after it shall end? How, indeed, could it have beginning or end? That time as well as space means infinity has led some to regard the two as identical. In the assumptions which make up algebra, this may be true. But with our own eyes we can see a tangible bit of time, a sample—not a fraction, for infinity is indivisible—to be quite unlike a sample of space. Ten hours can not be balanced against ten miles.

The point is this: in the majestic whirl of astronomy in which cosmic order seems the one dominant feature, do we get a glimpse of the heart of the infinite? Do we find here the master key which shall tell us "what God is and what man is?"

The students of microphysics, in making their plea, are not less strenuous than the astronomers. "Large" and "small" are relative terms only. Each of us brings what he knows to the measure of a man. But in the almost infinitely (never quite infinitely) small, the phenomena of orderly change on which all scientific conception must be based are just as tangible as suns and planets. The molecule, as we used to describe it, is made of atoms, that which "can not be cut," as the Greek term signifies. But the skilful experimenter now cuts up his atoms into electrons, each atom being conceived as a minute planetary system, with its own central nucleus and its revolving electrons, each with its own acceleration and retardation under influences of heat or electricity. In this view, the expanse of the universe is conceived as "a restless troubled sea," yet a sea in which reigns a majestic cosmic order.

There is a disposition among physicists to regard theirs as an exact science, because its units, as far as we know, are alike and invariable. Accordingly these submit to be counted or measured, and for purposes of science, a thousand electrons are all of the same nature. They have no individuality, and for that matter, except for difference in bulk and station, we find little individuality in planets or stars.

Let us now go beyond the current discussion and search for our master key in biology, the realm of the inconceivably variable. The make-up of animals and plants, to be sure, lies within the range of the science of chemistry, though their essential quality, that of being "going concerns," seems to transcend chemistry. Their substance is subject to physical laws; but they have in addition what planets, molecules and electrons do not possess, functional organization. And in the survey of organization we find an array of marvels, subject to constant variation in time and space, beyond the capacity of suns or electrons, though the activities of life are conditioned by both.

Whether or not there exists an extra-physical or vital force, a matter which (as Dr. Brooks used to say) "we shall never know until we find out," one recognizes certain features of organized life which contrast sharply with those of unorganized matter. With organization, for example, we have *individuality*, no two individuals being actually alike.

We also observe *irritability*—response to external stimulus; *metabolism*—waste and the need of food; *reproduction*—the casting off of matured cells to form new individuals, this including the fact of sex and its varied ramifications; *mortality,* under its phases of growth, maturity and death; and evolution, the capacity to develop new forms through the normal processes of *heredity* and *variation,* and the directive influences of *selection* and *segregation.*

More marvelous than gravity or chemical affinity, and even more elusive still than the visible phenomena of organic existence is the development of the hidden powers in the cells cast off for reproduction. Bound up in the structure of the microscopic chromosomes of the cell-nucleus, in some inscrutable fashion, are the traits of ancestry which tend to make each living being, under similar circumstances, react to life as did its ancestors, the fact of double parentage operating to provoke or insure constant change from generation to generation.

One illustration out of thousands occurs to me as I write. In the warmer parts of the Pacific lives a genus of large, mackerel-like fish, the Oceanic Bonito, called in the South Seas *Aku* or *Atu;* in Japan, *Katsuwo.* These fishes travel about in mighty hordes, one ninety-six miles long having been reported as passing Hawaii. They cast their spawn in the open sea, the egg-cells, minute, transparent, practically invisible, carrying a bit of food-yolk to feed the developing young, the sperm-cells without yolk and therefore ultra-microscopic, but each with rudder-like tail, moving about by the million, yet soon to die in enormous numbers, wasted like the wind-blown pollen of the pine.

Each quiescent egg-cell as well as each wandering sperm-cell carries the hereditary tendencies of his race—to develop a backbone, gills and fins, to take a fish-like form, which in time will assume the mackerel traits of thin scales, teeth, skeleton and all the other details. Development, however, depends upon the union of sperm and egg, without which both speedily die. That union accomplished, the embryo begins to show the special traits of its genus, the chief one being a peculiar interlocking of certain vertebral processes. Later each little fish takes on the special form and the four long, curved, black stripes of its particular species. Lastly, no two individuals, no two germ cells for that matter, being ever exactly alike, a small degree of variation from all its fellows appears in each completed *Aku.*

A similar illustration could be drawn from the life history of any animal or plant, though usually on a smaller numerical scale. Yet the pollen in the pine woods of Michigan, blown by the wind and beaten down by rains, covering ponds with what is called "sulphur," presents the same phenomenon. Each pollen grain and each ovule in the maturing cone dies unless mated. Every pair thus mated bears in its nucleus a composite image of its own kind of pine tree, to be developed at last as a complex of the two.

It was in a living "flower of the crannied wall" that Tennyson sought for the master key. This is perhaps infinitely beyond our reach; but in the organization of living matter we may at least come as near to the understanding we seek as through the sublimity of the universe or through its minutest atoms.

Still another thought arises. No tiniest organism lives to itself alone. In the conjugation of cells in one-celled creatures and in the aggregation of cells by which complex forms have been gradually evolved, we recognize a process of harmonious cooperation which rises in continuous series to the incalculable complexity of the human brain.

In cooperation toward common ends or to meet common needs, even among the lowest animals, we note the stirrings of the abiding principle of altruism. This reaches its height, in humanity, in the love of the family. The broadening and intensification of altruism is as much inherent in the universe as the movement of planets or electrons. Do we then find in love the master key?

Or shall we look still farther? Tyndall somewhere asks the question as to whether he knows all that can be known about the formation of a crystal. That he can not believe. Has anybody already said the last word concerning this relatively simple process? Have we indeed said the last word concerning anything whatever in the universe? Huxley asserts that "nothing endures save the flow of energy and the rational order that pervades it." Can we define—can any one define—this "rational order?" While the imaginations of all races have been busy describing God's attributes, stating those in terms of human experience, is not His essence inscrutable, inconceivable, unknowable? Is He not infinite? Who grasps infinity? Can we coherently try to compass the source of all being, of all energy, of all order? "Canst thou by searching find out God?" On the other hand, can we conceive of His non-existence? In view of all we know or see or feel, can we assume that no rational order lies in it or behind it? Huxley, impatient with conventional orthodoxy and alike with conventional pessimism, says bluntly:

> I am utterly unable to conceive the existence of matter, if there is no mind to feature that existence. . . . The problem of the ultimate cause of existence is one which seems to me hopelessly out of reach of my poor powers. Of all the senseless babble . . . the demonstrations of these philosophers who undertake to tell us all about the nature of God would be the worst, if they were not surpassed by the still greater absurdities of the philosophers who try to prove that there is no God.

It is plain that neither in "systematic theology" nor in science has the last word been said. In astronomy, in physics, in life, in space, in time, in thought, we find ourselves baffled in the face of infinity. The master key which shall open all doors which lead to the Creator no man has yet found. Does not that also lie within the gates of infinity?

THE FISHERIES OF ALASKA[1]

By The Honorable HENRY O'MALLEY
UNITED STATES COMMISSIONER OF FISHERIES

My extended travels throughout Alaska have thoroughly impressed me with the enormous extent of that territory. A map of Alaska placed on a map of the United States would extend from Georgia to Oregon. This is due in part to the long Aleutian chain of islands, but, as the territory contains 580,000 square miles, it is nearly equal to the area of the United States east of the Mississippi River.

When I mention Alaska you probably see visions of ice, snow, polar bears and gold. Little, if any, thought is given to the fisheries. Yet, since the purchase of Alaska from Russia in 1867 for the modest sum of $7,200,000, the territory has produced more in fishery products than in any other resource. The total value of such products, including aquatic furs, since the purchase of Alaska, is about $625,000,000 as against about $517,000,000 for all minerals. The present annual value of the fisheries is about $40,000,000 as against a much smaller sum for minerals.

While the Alaska fisheries include salmon, halibut, cod, herring, shrimp, clams, whales and other products, it is the salmon which gives Alaska its chief commercial product and the world two thirds of its canned salmon.

The story of salmon is one of great interest. As natural history, it is also a story of ruthless destruction of one of the greatest of our natural food assets. It has been a constant struggle between those who look to the next generation and those who seek immediate profit.

[1] Broadcast from Station WRC, Washington, October 29, 1925, under the auspices of the Smithsonian Institution and the direction of Mr. Austin H. Clark.

The salmon, once the pride of the streams of the North Atlantic, have vanished. In twenty-eight rivers between New York and the Canadian border millions of salmon once spawned. To-day only a few thousand survive, and the Penobscot alone receives their visits. A valuable food supply has been completely exterminated on the Atlantic. On the Pacific a similar process is going on, but fortunately time still remains to save there a remnant of the great schools which once swarmed its waters. Many Pacific streams are already depleted. Some can still be saved.

In at least one respect the salmon is unique among living things. Hatched in some quiet lake or stream at the headwaters of a great river, it stays there but a short time and then swims to the sea—where, no man knows. The life of a salmon ranges from two to seven years. The age of an individual is readily determined by observation of the rings on the scales under a microscope in somewhat the same manner that a tree's age is told by a cross-section of its trunk. For some years the salmon stays in undiscovered ocean depths, but never does it forget its birthplace. When its life span is about spent, it returns again to the spot where life started and there spawns and dies. The period of absence varies with different species, but all have this common homing instinct—that where life commenced for them, there it must end, and there their descendants must likewise start life.

This peculiarity has one inevitable result. Since each stream is visited only by the fish hatched in it, when the as-

cending salmon are all once caught and propagation prevented, that stream ceases to be a salmon stream. No other salmon will visit it. It can be restocked only artificially.

There is an unexplainable peculiarity in the salmon runs. They are not uniform from year to year. They show great fluctuations, high years followed by lean ones, in cycles of some regularity. Conclusions as to the condition of any stream must therefore be based upon the consideration of runs for a series of years, deductions from figures for only a few years being wholly unreliable.

Almost the entire commercial catch of salmon is made from the mature schools on their way to the spawning grounds. In districts where streams enter boldly on the outer coast line, the salmon are not seen and are not subject to capture until they school up immediately outside the river's mouth. But in districts like southeastern Alaska, they traverse long salt-water channels on their way to the spawning beds and must run the gauntlet of attack for the entire distance. Unless their migration paths are learned, and a close watch kept on each stream to assure the escapement of an adequate reserve of spawning fish, depletion will surely occur.

In the commercial fishery three chief methods of capture are used—traps, seines and gill nets. Hand lines, wheels and dip nets are used in a minor way.

After removal from the water, the salmon are taken to canneries where they are cleaned by a machine known as the "iron chink," so called from the fact that it has taken the place of many Chinese who formerly cleaned the salmon by hand. The fish are then carefully washed and cut by machine into lengths suitable for the cans. Before the filling machines deposit the salmon in the cans a quarter of an ounce of salt is measured in. Tops are then put on but not tightly sealed. Next, the cans go to the steam boxes for fifteen minutes, where the air is heated and exhausted. Then they are hermetically sealed and sent to retorts, where they are cooked in steam for an hour and a half. After being cooled and labeled they are packed in cases, usually forty-eight to the case. It will be seen that practically all the work of salmon canning is done by machinery and the product is scarcely touched by the human hand.

At this point I wish to call attention to the great food value of canned salmon. There is nearly always considerable waste in meats, while with salmon there is nothing to throw away but the can. Meats spoil quickly in the home, but canned salmon, if unopened, will keep indefinitely. All five species of canned salmon are highly nutritious and when canned differ chiefly in color, firmness of flesh and proportion of fats. The red, or sockeye, and the chinook, or king salmon, command the highest prices, but the coho, or medium red, and the pink, or humpback, are excellent in flavor, though the flesh is paler and not quite as firm as the red or chinook. The chum salmon has a pale or yellowish color when canned. It is the least expensive, but is rich in food values. The Bureau of Fisheries will gladly furnish on request a variety of recipes for preparing canned salmon.

The laws and regulations for the conservation and protection of the fisheries of Alaska are administered by the Department of Commerce through the Bureau of Fisheries. This is a highly important and responsible duty, as it involves control of an industry whose investment runs into many millions of dollars and which gives employment to more than twenty-five thousand persons.

The Yukon River affords an example of the provision which the department makes for the welfare of natives and local residents. Some years ago canneries at the mouth of that river, beyond the jurisdiction of the department under the law then in force, threatened the future of the salmon runs. The natives

suffered hardships, but the department was powerless to act. Under the new law regulations have prohibited commercial operations at the mouth of that stream, with the result that an ample escapement of salmon is assured for the future, and the resident population will not suffer from a lack of salmon due to commercial activities. The law provides for uninterrupted fishing by all residents to provide food for themselves and their dogs, which are so indispensable to winter travel.

In protecting the fisheries of Alaska, an active patrol is carried on throughout the season, which extends from May through September, depending on the locality. As there are 130 salmon canneries in Alaska, located all the way from the southern boundary to Bering Sea, the magnitude of the undertaking can be appreciated.

Preliminary returns indicate that the total pack of salmon in Alaska in 1925 will be about 4,300,000 cases as compared with over 5,200,000 in 1924. This decrease of about 900,000 cases, or approximately 18 per cent., was due largely to the light runs in Bristol Bay and Alaska Peninsula regions. Other factors were involved, including the regulations of the department necessary to rehabilitate depleted runs.

The restoration of salmon runs which have been seriously reduced or even almost eliminated through intensive overfishing is an interesting problem and one in which successful results will undoubtedly follow. It will require a number of years, but eventually, through the regulations of the department, the business will reach the maximum of productivity. When a ton of coal is removed from the ground, there is no way whereby man can replace it, but obviously the restoration of a natural resource like the salmon fishery is possible through intelligent methods of conservation.

The great value of the Alaska salmon is apt to cause one to overlook the other fisheries of the territory. The halibut fishery, chiefly on offshore industry, is protected by an international treaty between the United States and Canada. Halibut taken on the offshore banks are landed in Alaska, British Columbia and Seattle. Large quantities are frozen or packed in loose ice and shipped to eastern markets. In fact about 85 per cent. of the halibut come from banks off Alaska.

The herring industry yields products valued around $2,000,000 annually. While the chief use of herring is for human consumption, large quantities are used for bait in the halibut fishery. In addition, herring, of the smaller sizes less desirable for salting, are used in the manufacture of oil, fish meal and fertilizer. Part of this oil is later used in making edible fats, while the fertilizer is an indirect food producer through enrichment of the soil. The herring fishery, which is chiefly an inshore industry, is far from being developed to its potential capacity. The whaling industry is confined to the waters about the eastern end of the Aleutian Islands, where it is of considerable importance. Last year 283 whales were caught in Alaskan waters. Alaska also yields clams and shrimps of fine quality, and the commercial fishery for both is assuming important proportions.

In conclusion, I want to leave with you one further thought, namely, that Alaska, with its splendid mountains, magnificent glaciers and other natural beauties, all of which are easily and inexpensively reached through the wonderful inside passage of one thousand miles or more from Seattle, has also a further fishery charm for the tourist or casual visitor as well as for the resident. I refer to the angling. The waters abound with trout and other game fishes. And if one is fortunate one may enjoy the thrill of landing a fifty-pound king salmon on a trolling line. Let me urge you to visit Alaska at the first opportunity.

ANIMAL VOICES

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In the discussion of the various noises made by animals the natural tendency has always been to argue from the point of view of a human being in a highly organized society carefully protected from all his enemies. By such an individual any sort of sound can be produced with safety, and sound production has been crystallized by custom into expressions of emotion wholly impossible for the savage tribes living in constant fear of other tribes about them, still more so for the animals.

We recognize, of course, certain fundamental sounds, quite uncontrollable, like screams of pain and howls of anger, but beyond such primitive types of sounds as these it does not seem possible to compare the sounds we make with any of the sounds made by the animals.

No plausible reason so far has been shown for the very diverse voices of the animals. Especially in the case of birds sentiment is commonly supposed to play a leading part. But every living creature is throughout its life so persistently beset by enemies that sentiment as understood by us can scarcely enter into its existence. Male creatures are supposed to sing in order to attract and please the females. But there is little evidence in most cases that females are attracted or are pleased by the songs of males. The male is probably the noisy sex, simply because it does not produce eggs or young and hence has considerable surplus energy available for other purposes.

Let us look more closely into sound production by the animals.

Life on the earth exists in alternating periods of light and darkness of, on the average, the same duration. Besides the difference in the amount of the illumination the day is usually noisier than the night because of the more general motion of the atmosphere. Diurnal creatures are very varied in their coloration and if they live in open places or above the protection of the foliage are often very gaudy in those regions where the light is strong. They are mostly silent, especially the less active and less conspicuous types like the mammals and the reptiles and the numerous crawling insects, bugs, caterpillars, young grasshoppers, etc. Extremely active kinds, like small birds that live exposed in open places or above the foliage, large birds of meadows, strands and marshes, the adults of grasshoppers, cicadas and some butterflies, are often very noisy, while very nearly all diurnal insects make a noise in flight. The songs, chirps or other sounds produced by these are almost always high in pitch and readily perceived.

Nocturnal creatures are much less varied in their coloration than are those that move about by day, mostly dull or mottled, never gaudy, though some nocturnal moths are rather bright. With the setting of the sun the wind dies down and with it the rustling of the leaves and branches so that the night is quiet in comparison with the day. But in contrast to these physical conditions most night-ranging animals are noisy, many extremely so. As examples may be mentioned the foxes, coyotes, wolves and lynxes, jackals, hyenas, lions, tapirs,

bats and many other mammals, at certain times the very numerous kinds of frogs and toads, nocturnal lizards like geckos, nocturnal birds like goatsuckers and owls and very many different kinds of insects, particularly some grasshoppers, katydids, locusts, crickets, and their allies, fulgorids, and some others. While the cries of animals in the daytime are almost always more or less high in pitch the sounds produced by the nocturnal types, though usually less varied for each species, have a much greater range; they may be either high in pitch, sometimes very high like the squeaking of some bats and the stridulations of some insects, or low like the roaring and the bellowing of the larger mammals and of the larger frogs and toads.

Many diurnal creatures when they move give out rustling body sounds like the birds and butterflies, while the corresponding forms of nocturnal habit have various special adaptations which make their flight quite noiseless as in the goatsuckers and owls and in the great majority of moths. These adaptations may or may not be combined with a loud voice.

The nocturnal creatures best protected from attack, such as the armadillos, skunks, porcupines, hedge-hogs, nocturnal snakes, and large and powerful predaceous insects, nearly all are voiceless or practically so.

Among all types of animals brilliancy and boldness of color pattern are chiefly characteristic of the more active, more restless, more exposed and more numerous males, more rarely and only under special conditions characteristic of both sexes. In the same way the possession of a voice, especially of a loud and high-pitched voice, is, generally speaking, confined to males, but under special conditions may be characteristic of both sexes.

Very many of the most vociferous songsters among the birds are brilliant males whose mates are dull in color with merely a high-pitched chirp or all but voiceless, as among the finches, tanagers, orioles and warblers, or to speak more definitely as in the goldfinch, indigo bird, rose-breasted grosbeak, scarlet tanager, baltimore oriole, bobolink and redstart. But very many other songsters are males, brilliant or dull, of the same color as the females, as in the song and other sparrows, most thrushes, larks, wrens and allied types, some orioles, some hummingbirds and various other kinds.

There must be some special meaning in the curious though well-known fact that our gaily colored song birds like the tanagers and orioles after the breeding season change from their brilliant livery to the dull garb of their females and at the same time lose their voices; or more properly with their assumption of the females' habits they adopt the females' voice and dress.

Gregarious birds usually are noisy, like the parrots, shore birds, geese and many ducks. In some gregarious birds, as certain pigeons and such ducks as golden eyes or "whistlers," the noise they make arises wholly from their wings.

No bird is wholly silent. Practically all the smaller birds have a high-pitched chirp and the males at times a song as well; the larger have a varied range of cries. Many in addition to their vocal efforts produce a wide array of sounds in other ways. Such are the woodpeckers, which have the habit of tapping with the bill on any resounding surface; many gallinaceous birds, ground-frequenting finches like the towhee, and some others, and certain other kinds, that make a rustling noise by scratching twigs and dead leaves with the feet; such birds as storks and owls that make a clattering or snapping with the bill; and many birds, particularly some pigeons, ducks and shore birds, with very noisy wings. In a few birds practically the only sounds are made by non-vocal methods.

In the spring with us the arboreal and terrestrial frogs, like the tree and wood frogs and the toads, collect in pools to spawn. At this time they are very noisy. Only the males sing, and the usual idea is that they do this to attract the females. But we have no evidence that the females pay much attention to the song. Collected from wide areas in small pools and puddles, the males could easily find the females without recourse to vocal effort just as do the males of certain turtles, like the sculptured turtle, which, though primarily terrestrial, mate in ponds and streams in spring.

In all the very numerous noise-producing insects the sexes are alike in color, though the song is in by far the larger part confined to, or much louder in, the males. Some insects, like the death-watch, make use of tapping on hard surfaces somewhat as the woodpeckers, while very many, not usually considered "vocal," like some birds have noisy wings.

These, briefly stated, are the facts that we must harmonize in any explanations of the meaning of the sounds made by the animals. The significance of these sounds undoubtedly is varied; but at the same time there must be one major meaning to which all the others are subordinate.

Let us begin our inquiry into the significance of animal sounds with a mention of the simplest and most constant sound in nature, the washing of the sea. Waves breaking on the shore and the white caps on the open ocean give forth a high-pitched hissing sound, consisting of an infinite number of separate sounds arising from the breaking bubbles which rapidly succeed each other.

Prolonged interrupted sound is intensely disagreeable, and soon becomes distressing. We all have noticed this in the prolonged ringing of an electric bell, in the continuous rumbling of an idling motor engine, and in other ways. Being high pitched, the hissing sound of breaking waves has a marked directive quality; it is easy to perceive its point of origin. Being unceasing and interrupted it is distressing and repellent, and all the more sensitive sea creatures try to keep away from it. Whales, porpoises and dolphins and many fishes keep always well off shore, guided apparently by these repellent sounds, while on a windy night various other types of life which normally would come up to the surface stay well beneath it. The simple breaking of the waves is of immense importance to sea creatures as an index of the dangers that they run. In times of storm the repellent sound increases and by this they are warned to keep further from the shore and further down beneath the surface.

The various noise-producing fishes all make monotonous interrupted sounds, usually low in pitch and most deceptive in direction. The few crustaceans that are sound-producing make a continuous clattering or snapping noise.

All these sounds heard beneath the surface of the ocean have the same repellent quality. They may be called "Keep away" sounds because of the natural reaction to them.

Prolonged interrupted noises are very commonly produced by land-living creatures. Perhaps the most typical of such "Keep away" sounds on land are the high-pitched rattle of the rattlesnakes and the loud hissing of the cobras, or the rustling of dry leaves by other snakes or by ground-frequenting birds. The hum of the mosquitoes and the buzz of the wasps and bees and flies are also good examples. If we hear these snakes or insects we instinctively recoil from them, even if we have no idea what they are. The buzzing of a harmless bee-fly in a room is just as distressing as the continued buzzing of a hornet, and the sudden hissing of an unsuspected snapping-turtle in New England will make

you jump as quickly as the hissing of a cobra out in India.

It seems self-evident that such sounds as these are primarily protective in their nature and are admirably adapted to deter an enemy from examining too closely into their point of origin.

Prolonged interrupted sounds are characteristic of all the noise-producing insects, crickets, katydids, grasshoppers, locusts and their allies, cicadas and fulgorids, beetles, moths and butterflies, spiders and centipedes, and of most flying insects, especially the flies and hymenopterous types, the beetles, bugs and others. The details of these insect songs, like the ways in which they make them, vary very greatly, but the general principles are the same in all. Some of the small birds, especially among the sparrows and the tanagers, and certain of the smaller rodents have just the same type of song. The cries of the companies of toads and tree-frogs in the springtime and the incessant cries of many flocking birds probably are deterrent cries of the same nature, at least primarily.

These also seem to be protective sounds developed to deter their enemies. If heard too near all of them to us are disagreeable, and there is no reason to suppose that their effect is different on the animals. Some few things will follow up these sounds and catch the singers, having learned thus to reverse their normal instincts. But such reversal of a normal trait is not by any means unusual and does not affect the general idea. The cannibal fishes of the South American rivers, for example, are strongly attracted by the same hissing sounds which are so very repellent to nearly all other fishes.

In the case of protective coloration each individual must be so garbed as to be at least conspicuous. In the case of protective sound production a part can be of service to the whole except in those conditions, as among the flying insects, where the individuals are emphasized. Thus it is that throughout the animal world songs are mostly peculiar to one sex, the male, which has assumed the duty of this type of protection while the females lay the eggs or rear the young.

Very many of the birds and mammals and some of the amphibians, if they are roughly seized or badly frightened, emit a single high-pitched shriek or a more or less extended series of high-pitched cries. These high-pitched cries of pain and fright have a marked directive character and no repellent quality. They attract immediate attention and at the same time allocate the creature giving them. We recognize at once the similarity of these cries of distress, no matter from what animal they come; but why should they all have this common quality? They are "Come to me" cries wonderfully perfect in their action. Any predaceous creature will recognize such cries and come at once to the spot from which they issue. But any predaceous creature keen in the capture of the animal in obvious distress will in most cases also be an enemy of the aggressor. The former by a high-pitched shriek of pain deliberately calls up an enemy to escape the latter. In the vertebrates these cries are characteristic of both sexes and especially of the young. They occur in a few insects; you can hear the male cicadas give them when they are pursued by cicada wasps.

As an example of how effective such a cry may be, I was recently in a field in Essex, Massachusetts, when I heard a constant squeaking in the grass. It was easy to determine its exact point of origin. There lay a small black snake with a young meadow mouse (*Microtus*) in its jaws. The snake made off at once holding the meadow mouse, caught firmly by its side, high in the air; but soon it dropped the mouse and both

snake and mouse scurried to safety. By its loud persistent squeaks the mouse had led me to the place where it was in trouble. The snake on seeing me approach too near let the little mouse go free.

The smaller birds commonly make use of this "Come to me" type of cry to frighten intruders from their nests. Thus the common robins give forth loud and piercing cries with the certainty of attracting to the spot any prowling hawk or owl or other enemy of the nest robber which itself will not disturb the nest and which they can escape by dodging through the branches. The "Come to me" cries of robins are nothing but invitations to their enemies which are thus called in expectation that they are equally the enemies of the prowling thief.

In this connection it is interesting that badly wounded birds or mammals seldom make a sound; they try to hide or to be as inconspicuous as they can. If seized, however, or badly frightened by a near approach, they commonly give vent to cries, and sometimes under these conditions birds will sing.

Most small birds, especially the very active ones like the finches and the warblers, from time to time emit a sharp and sudden chirp, whistle or other sound of a similar nature. This locates them at once to all the animals in hearing distance. But they are always on the move. No sooner do they chirp than they go on to another place. Thus they continually call attention to the places they have left and the chirp is never sufficiently prolonged to indicate what direction they have taken. Because of their superior activity and their power of flight these "Here I am" cries are especially characteristic of the birds, particularly of the smaller birds, but many active mammals have them also, like the tapirs, forest dogs and certain of the monkeys in South America, and various small rodents and other mammals elsewhere. They are rare among the insects, but some have them, like "whip-cracker" butterflies (*Amphichlora*). Many birds give these cries when they are on the wing, especially at night; you hear them from the warblers on migration and just before the rises of the strongly undulating flight of goldfinches and of some other birds.

This type of cry is easily reduplicated, varied and expanded into a more or less prolonged and complicated song, and in the birds, indeed, all possible intergrades occur between a single chirp and a perfect and continuous song. But if bird songs are in reality a development from the isolated single chirps of little birds they must necessarily in some way carry out in a more extended form the original significance of those chirps from which they had their origin.

Our attention is at once attracted by the songs of birds, and few people are so callous that they will not glance in the direction of a performing songster, which is almost always easily determined. We have no enmity toward the little birds; they please us with their songs and they destroy the insects that attack our crops. We therefore look on almost all of them with tender sentiment. But let me repeat that every creature in the world is so beset by enemies that it leads the most precarious sort of an existence. Any false step means its death. Any transgression of the rigid limitations within which life for it is possible, whether by individual variation in form or structure or by unfortunate accident, means the prompt elimination of the individual so transgressing. It is inconceivable, therefore, especially in view of the common qualities of all bird songs, that the voices of the singing birds should not be a part of that delicate adjustment which we

recognize in form and structure and in color. Animals that seek their prey by day, except the majority of the parasitic and predaceous insects and some mammals which are guided largely by their sense of smell, chiefly depend on sight; particularly are they quick to detect motion. Diurnal animals therefore are wonderfully varied in their coloring, each type of color being especially adapted best to conceal its wearer from his enemies in his normal habitat when acting in his normal way. But many predaceous things that hunt by day are guided by the ear as well as by the eye. Is it not quite as necessary, therefore, that their intended victims should be able to deceive one organ as the other?

Among the song birds there is little evidence in most cases that the females pay much attention to the songs of males, though it is probable that they serve to some extent, in the cooing of the doves, for instance, or the creaking of the grackles, as a sex stimulus. The male is the aggressive sex, and the males therefore occupy positions where they can best watch out for females. In such positions, in a tree top, on a bare twig or a branch end, on an exposed rock or hovering in the air, they are especially subject to attack by all their winged enemies. Their coloration at the mating season, often very bright in startling contrasts and widely different from the somber females, is especially adapted to conceal them when they are on the lookout for their mates. The movements of small birds are very quick and discontinuous, lightning-like action alternating with almost rigid immobility; this adds to the effectiveness of their concealing coloration in giving a constant change of background so quickly made as to be difficult of detection.

The song birds commonly so called all have high-pitched voices; but the songs, unless a disagreeable buzz or trill or rattle, or otherwise similar to the "Keep away" cries of insects, is always modulated and composed of varying notes of different pitch and quality. Sometimes in searching for a songster in a tree top or in trying to locate a skylark or a longspur in the air we have some difficulty in determining his exact position. Yet from the ground he usually stands out against the sky or the blurred outlines of the distant vegetation, and we get his notes in their unaltered values. The song in other words proclaims his presence, but does not reveal so clearly as it might his exact location.

But birds when singing have no fear whatever of ground-living things. It is the hawks especially that are their enemies. A hawk on the lookout for small birds cruises about in an erratic course at the rate, say, of about thirty miles an hour. We all have noticed how much higher is the pitch of the whistle of an approaching than of a retreating locomotive, and the average train does not travel with the speed of a cruising hawk. It is therefore evident that to a hawk the same bird cry will have an infinity of different values between two wide extremes. This would confuse us hopelessly, but the hawks undoubtedly discount this effect. If the hawks have trained themselves not to be deceived by the variations in the pitch of animal cries and in the calls of birds resulting from the speed with which they fly, as it is quite logical to assume they have, we at once see a simple explanation for the songs of birds. A varied song composed of notes of different pitch would be most hopelessly confusing to a hawk. The high notes would indicate to him that he was flying toward his intended victim, the low that he was flying from it. In other words a varied song would most effectively conceal the whereabouts of the singer from any creature passing

rapidly through the air. The songs of male birds in the mating season therefore seem to be nothing more nor less than a development of their normal calls into a medley of sounds most admirably adapted to conceal their true location from their enemies that fly and hunt by ear, just as the special colors most of them assume are especially adapted to conceal them from their enemies that fly and hunt by sight. By the development of songs and special plumage in the mating season male birds are enabled to occupy exposed positions and thence watch for the females which otherwise they could not do.

The same "Where am I?" quality is characteristic of the noise produced by many of the larger birds in the courting season, though these make use of most deceptive low-pitched sounds, and in their vocal efforts a sexual significance is much more evident. Good illustrations are the booming of the bitterns and the drumming of the ruffed grouse. The cries of certain of the larger frogs and toads are much the same in nature. This type of cry among the mammals is exemplified by grunts and growls given mostly when alarmed and usually by both sexes equally. I once disturbed a Barbary ape which was feeding on the ground under a fruit tree. The fierce resulting growls seemed to be given out from a whole troop of monkeys all about me, though only one dashed off through the undergrowth.

Whereas by day all creatures are protected from their enemies by very varying types of coloration, this protection largely fails at night, for nocturnal creatures hunt chiefly by sound instead of sight. For such of them as have their eyes especially adapted for nocturnal vision, like owls and lemurs, day-time colors are of course largely ineffective because of the change in color values.

To counterbalance loss of protection afforded by the possibilities of varied coloration nocturnal creatures, especially the insects, have developed to the maximum the protective and other possibilities of sounds.

The period of greatest danger for all creatures is the twilight when altered color values have destroyed the significance of protective coloration, diurnal animals have not as yet composed themselves for sleep, nocturnal animals are awakening, and both diurnal and nocturnal predators are active. All animals need protection most at twilight, and for this reason this is by far the noisiest time of day or night. The singing of diurnal birds at evening and again at dawn is nothing more nor less than a measure of the special dangers that they run at that particular time. Like blinded birds they are doing what they can to ward off unknown dangers. Midday, when protective coloration has its greatest value, and midnight on dark nights are the safest times for all living creatures, and at these times animal sounds are least in evidence.

Especially characteristic of nocturnal creatures are "Keep away" cries of all sorts and descriptions, emanating chiefly from an infinite variety of insects and from small frogs and toads. In addition to the insect types vocal by day are various others, like fulgorids and numerous large slow-flying droning beetles, and some noisy moths like hawk-moths.

"Here I am" noises are not common among night-ranging creatures, and are mostly confined to very active mammals, such as mice, forest dogs, foxes, bats, tapirs and small nocturnal monkeys, and to some of the smaller frogs.

"Come here" cries are often heard at night emanating from the same creatures that would give them in the daytime under similar circumstances.

The "Where am I?" type of cry is quite common in the night, and is especially favored by nocturnal birds, like goatsuckers and the smaller owls, and by those diurnal birds that sing at night, and in a different form by large frogs and toads and by certain large male mammals. Among nocturnal predators, like the large owls and carnivores, this passes into another sort of cry, the "I'm after you" exemplified by hoots, roars and growls coming seemingly from nowhere and presumably effective in disconcerting other creatures and so terrorizing them as to throw them off their guard. Some large owls combine these two types of cries, giving a mixture of high-pitched shrieks and low-pitched hoots as they fly about. Some active predaceous mammals do the same.

As at night the wind usually dies down and the protection afforded by the rustling of the leaves and branches against the detection of similar sounds of animal origin is dissipated. Such sounds are more especially the ordinary sounds of flight among the birds and insects. Therefore, most of the night-ranging birds and some of the night-ranging insects, especially the moths, have developed an almost noiseless flight both to escape detection and to facilitate the capture of their prey.

Special conditions of existence call forth special types of sound production. Those animals that live by day in dimly lighted places act as regards sound like animals in twilight. Open fields in the late summer, when the grass has ceased its earlier luxuriant growth and the blades are withering, no longer shield from sight the grasshoppers, now fully grown, as they did before. To compensate for this loss of protection from the vision of their enemies they develop voices of the "Keep away" type in an endeavor to counteract lack of concealment by deterrent noise.

Summary

Like the various colors with which they are adorned, the similarly varied voices of the mammals, birds and reptiles, amphibians and fishes, and the insects are primarily protective in their nature. By their colors they deceive the eyes of enemies; by the sounds they make they deceive or irritate their ears.

While color is individual and each creature therefore must assume a livery best suited to its particular environment, this is not so in the case of sound production. Here a portion of the individuals can protect the whole. Thus sound production is chiefly a function of the males, correlated with the females' duties of producing eggs or rearing young. But whenever any forms of animal life are individualized, as in the case of bats, birds or insects on the wing, both sexes become noise producing equally.

The sounds produced by animals, sometimes with the aid of inert objects such as dry leaves or the dead trunks of trees, are of several different types.

The majority of animal sounds, especially among the insects and the lower vertebrates, are high-pitched prolonged interrupted sounds which are extremely disagreeable and are designed to deter an enemy from a close approach. These may be called "Keep away" sounds.

Uninterrupted high-pitched cries or shrieks have a directive character without any deterrent quality. They attract an enemy at once. They are especially characteristic of animals in pain or trouble and are designed to bring an enemy in the expectation that the enemy will also be an enemy of the attacking creature. These may be called "Come to me" cries.

Somewhat similar are the "Here I am" cries of little birds and other very active creatures always on the move. These cries call attention to the place

where they were given but which the bird has left.

The isolated chirps of birds grade into the complicated songs of the males of song birds. These are hunted by the hawks flying rapidly through the air. To a hawk in rapid motion the same sound will appear of widely different pitch according to the hawk's course in relation to the point of origin. A small bird's varied song would to a hawk suggest a single sound before, behind and all around it, thus serving to conceal the small bird's true location. The songs of birds are simply "Where am I?" sounds produced for the deception of their enemies at the times when they are most subject to attack. Many of the larger birds produce the same effect by sounds of a low pitch, as do various mammals and some of the amphibians.

Among nocturnal predators "Where am I?" sounds tend to become expanded into "I'm after you" cries—hoots, roars and growls—designed to terrorize their intended victims into a lack of their customary caution.

In addition to the primary function of the voices of the animals as explained above it is clearly evident that animal sounds have come to have several minor, though important, functions. For instance, they are evidently used as a sex stimulus, especially among the birds and the amphibians and in some groups of insects where they seem largely to replace the odors in the mammals and in certain insects, as the Lepidoptera. They are also of importance in keeping flocks and families together, especially among the birds, and in various other ways.

RADIO TALKS ON SCIENCE

THE EFFECT OF FORM ON MATTER[1]

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It is fascinating to watch the creation of a structure through the laying of brick on brick, or stone on stone, until, by gradual accretion, the structure assumes the form and dimensions sought, together with the symmetry and proportions which bring joy to the eye of the beholder, developed in it through the manner in which the units from which it is constructed have been placed. I have followed with pleasure the growth of many of the fine structures in Washington, among them several of its bridges, the Union Station, and the Lincoln Memorial. I have envied those engaged in the creation of these splendid productions of man and realized how properly proud each man who participated in any way in these achievements must feel whenever he views them.

It is also interesting to watch the demolition of buildings, to observe the bricks and stones being separated from one another and to see that, little by little, the interior is disclosed, ultimately to the foundation, so that the kinds of materials which had gone into the structure, together with the manner of their arrangement and services, stand revealed.

These two operations, constructing a building and wrecking a building, are examples of two processes widely made use of in the study of matter. In the wrecking of a building, by taking it apart, one conducts an analysis. In erecting a building, by putting together its component parts, one conducts a synthesis. Chemists largely employ analysis and synthesis in their studies of matter.

Given, for instance, common salt, which lends savor to our food, or sugar, which sweetens it, or a snowflake caught on a well-cooled coat sleeve, before proceeding to take them apart, that is, to analyze them, the chemist would closely view them, using a microscope by which the minute particles would appear so enlarged that their shapes and appearances would be readily discerned, and he would find each to possess a definite and attractive form, but that each form was quite unlike that of the others. He would pronounce them crystalline in structure. When given freedom of motion, the particles of each tend to produce these definite crystalline forms, and these forms are so characteristic for each substance they serve as means for the identification of the substance. The salt and the sugar were crystallized from solutions in water. The frozen water crystallized out from solution in air to fall as snow.

There are a multitude of crystalline substances to be found in nature. The diamond, ruby, sapphire, emerald; ores of iron, copper, silver, lead and other metals; and substances like graphite, gypsum and calcite may be prominently mentioned. Visit any mineral collection, such as that in the National Museum,

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and you will be charmed by the infinite variety and beauty of the crystals to be seen there and convinced that each substance has a figure all its own.

Having a collection of minerals of your own to choose from, if you were to select a specimen of lead sulphide, such as is used in many radio sets, and which is known as galena, you would find it to be a cube in shape and that, if you crushed it by a blow, the smaller particles also have this cubical shape. Likewise, if you were to select a piece of calcite, which may be styled crystallized marble, and crush it, you would find its characteristic form to appear in its fragments. The characteristic crystalline form of a substance persists quite to the limit of our vision, even aided by powerful microscopes. By the use of X-rays we have learned that crystalline form exists quite beyond that limit.

It is possible that while examining your crystal of calcite or Iceland spar, as it is also called, you put the transparent, colorless, glass-like crystal on a piece of paper which had a spot on it and noted, to your surprise, that you saw two spots where you knew only one to be. Perhaps, in your amazement, you turned the crystal about as it rested on the paper and were further surprised to see one spot rotate about the other. You were not deceived. It is a property of Iceland spar, because of its form and structure, to make you see double. Iceland spar consists of doubly refracting crystals.

Light, as you are no doubt aware, consists of waves oscillating up and down in many planes within a beam of light. Iceland spar, as noted, splits the beam. Nicol conceived the idea of so cutting and rejoining a piece of Iceland spar that but one portion of this light could pass entirely through the reunited crystal, and in the ray that passes all the waves vibrate in the same plane. Such light is called polarized light and the crystals, cut and arranged as devised by Nicol, are called Nicol prisms. With polarized light great marvels may be wrought.

Thus if we put one Nicol prism below the stage of a microscope and another above, at the eyepiece of the instrument, and allow light to enter the lower one, no light will pass through the upper prism—there will be absolute darkness—until the upper prism is brought into a nearly identical position, as regards rotation about the vertical axis, with the lower prism. Biot found there are many chemical substances which, either in the crystalline form or in solution, will rotate a beam of polarized light which is passing through them, and such substances are therefore called optically active bodies. Place an optically active body between Nicol prisms so "crossed" that there is total darkness at the eyepiece, and at once light appears; usually accompanied by most exquisite colors; so that, what with crystalline form and color, optically active bodies, viewed by polarized light, present some of the most lovely aspects man is permitted to view. Among the optically active substances is cane sugar, whose quality and purity are, because of this characteristic, ascertained by the polariscope—an instrument so constructed that a tube containing a prepared solution of the sugar may be placed between its Nicol prisms and viewed by polarized light. To-day large loans are placed on sugar crops and millions in duties are levied according to the results of the polariscopic measurements of sugar.

Wine-making is one of the oldest arts known to man. It is based on fermentation, which rivals in efficiency in changing matter the agent which transforms energy to produce light in the firefly, glow-worm and the animalculae, through which the waters of the ocean compete

with the aurora of the Arctic heavens. It may well be that fermentation and phosphorescence in living beings are due to the action of similar agents. The chemist early turned his attention to wine-making, and though undoubtedly much remains unknown to-day about this marvelous work of nature still much has been discovered.

In 1789, Scheele showed that tartaric acid could be obtained from argols, or the lees of wine, thus creating a new and important industry, for ever since cream of tartar, used extensively in "raising bread," and for other purposes in domestic life, has been obtained from the deposits of fermented grape juice. In 1822, Kestner discovered that the wine deposits yielded racemic acid also, which Gay-Lussac found, by analysis, is composed of precisely the same amounts of the same kind of elements as tartaric acid, yet the two are unlike in properties for, as shown by Biot, while tartaric acid is optically active and rotates polarized light, racemic acid does not rotate it at all.

This was the state of knowledge on these acids when Pasteur, in 1848, began a five years' study on them, eventually proving that racemic acid is composed of two different forms of tartaric acid, both of which are optically active, one however rotating the beam of polarized light to the right (and styled dextro-rotary), the other turning the beam to the left (and called laevo-rotary), and that they existed in racemic acid in equal proportions, so that they neutralized each other's effort to turn the beam of polarized light.

During this investigation Pasteur devised ingenious means for crystallizing out a salt of racemic acid by which he obtained small crystals alike in all respects, except that on one half of the crystals the ends were provided with a set of facets which were arranged about them in right-hand order, while on the other half similar facets were arranged in left-hand order. When, by the aid of a magnifying glass and forceps, he separated these he was able to produce three solutions: (1) of the original mixture of crystals; (2) of crystals having facets arranged to the right; and, (3) crystals having facets arranged to the left. On polarizing them, (1) was found to be inactive, (2) rotated the beam to the right, and (3) rotated the beam an equal extent to the left. More remarkable yet, Pasteur found that an organism, such as *Pencillium glaucum,* growing in a racemic acid solution, would devour the dextro-tartaric acid, and leave the laevo-tartaric acid untouched. Since then many other instances of racemation have been discovered among organic compounds and special micro-organisms that selectively feed upon one of the isomers, as such similar compounds as the tartaric acids are called.

Pasteur then passed on to the further study of fermentation, as exhibited in the making of bread and the brewing of beer, and, with the knowledge thus gained and the technique thus acquired, to the study of contagious diseases in the silkworm, animals and man with the result that he conquered virulent diseases like anthrax and hydrophobia; revolutionized the art of surgery and the practice of medicine; saved much suffering, extended life; and improved the conditions of living.

Some twenty years after the discovery of racemation by Pasteur, van't Hoff and Le Bel accounted for the optical behavior of the tartaric acids by the internal arrangement of the atoms in their molecules, and continued research has shown that the properties of matter are dependent not only on the kind of materials which go into the construction of their molecules but also the manner in which they are arranged.

THE AGE OF SYNTHESIS

By H. E. HOWE
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THE possibility of referring to "synthetics" in the title of a radio talk indicates the increasing number among the public that have become sufficiently interested in modern science to form at least a nodding acquaintance with it. At any rate a number of synthetic articles with which the public is familiar might be mentioned, but none of these are quite so beneficial as those to which reference will be made.

The world has consumed more metal in the last twenty years than in all the preceding twenty centuries. We use wood four times as fast as it is being grown, and certainly our coal and petroleum resources are being drawn upon at a rate far exceeding their replacement, if indeed they are being replaced anywhere on the earth. These and similar facts bring home to us the seriousness of the question, How long will the earth be able to maintain its population at anything like the present high level of civilization? Will the limiting factor be rainfall, upon which the production of food depends? Will it be the success which may attend our efforts to overcome the molds, yeasts, bacteria and insects which threaten our food supplies? Or will it be the extent to which the scientists are able to discover supplementary resources or synthesized materials to replace those consumed by an advancing civilization?

The scientist looks with considerable confidence to the future because of what has been accomplished and what he believes can be accomplished in future as the sum total of human knowledge increases. The scientist began his work long ago by first determining the constituents of the materials found on the earth's crust and in the atmosphere. He has since applied this information obtained by difficult analysis in stimulating productivity, as, for example, in the application of his data in the field of agricultural chemistry. There, certainly, increased production has followed the application of scientific principles discovered largely in the chemical laboratory. But the replacement of natural resources involves more than a stimulation of production. Many of our most important resources are not produced by annual crops and require a treatment quite different from that serving in some agricultural fields.

What is taking place in the use of petroleum serves well as an example of true conservation through efficient use. The multiplicity of internal combustion motors has made gasoline—once a nuisance to the refiner—the product he most greatly desires. Early in the history of petroleum refining the gasoline that could be obtained by simple distillation was all that was produced. This was seldom more than 10 or 15 per cent. of the oil distilled. Later the chemist showed how to recover the gasoline present in some types of natural gas and also that in the so-called casinghead gas which comes from petroleum wells. These two sources now account for more than nine hundred million gallons of gasoline annually. It was soon seen, however, that additional quantities of gasoline must be produced. The application of the principles of physical chemistry and of engineering has given us a series of cracking processes, so that today more than 60 per cent. of the petroleum subjected to the process is recovered as gasoline, while kerosene and other standard fractions of the oil may also be converted into satisfactory gaso-

line. Even higher conversion percentages may be expected in future.

By synthesis is meant the production of a material by scientific methods to reproduce or take the place of some compound found in nature. Within the present century and indeed within the present decade, many things have been successfully built up by man-devised methods, first in the laboratory, then in a pilot plant and now on a commercial tonnage basis. A few examples will suffice to illustrate why the chemist looks forward to a synthetic age.

At the present time a synthetic hard fat is produced from vegetable oils at an annual rate equivalent to the fat obtainable from seven million hogs. In addition many million pounds of oil are treated by the same process for technical purposes and for use in admixture with the synthetic hard fat. The process consists of adding the requisite number of hydrogen atoms to the liquid fat or oil molecule, whereupon it becomes a hard fat, taking the place of hard animal fats for many purposes. Simply stated, the process consists of treating the warmed oil with the gas hydrogen in the presence of finely divided nickel which takes no part in the process other than to promote the union of the oil molecules with the hydrogen. So long as America can produce such vegetable oils as cottonseed and peanut, it would be impossible to embarrass her by a fat shortage, while the value added to many grades of oil for manufacturing purposes, such as soap-making, has been so enhanced as to constitute an important economic item.

In 1898 Sir William Crookes predicted a famine because he foresaw the exhaustion of nitrates obtained at that time only from the saltpeter beds of Chile. Sixteen years later the World War was begun, the aggressor having perfected a synthetic process for the production of nitrates from the nitrogen of the air. Although first applied as a war measure, the synthesis of ammonia is of greater peace-time importance, since nitrogen is essential to food production and the vast quantities of nitrogen in the air must be fixed in some soluble form to make it available as plant food. Synthetic ammonia is the first step in a series of chemical processes producing a variety of forms of nitrates for plant food. Though this work was begun abroad, America is in position to take a place in the front rank of this work, due to the successful investigations at the Fixed Nitrogen Research Laboratory of the Department of Agriculture and the cooperation of many industrial chemists.

Until recently acetic acid, better known as the acid in vinegar, was made principally by the distillation of hard wood. Calcium acetate was the form in which it was recovered, and from this acetic acid could be produced. To-day this acid is being made in commercial quantities from acetylene, which in turn is made from carbide, and this is the result of a chemical reaction involving limestone and coal.

Another important synthetic material is methanol, formerly known as wood alcohol and until recently derived solely from hardwood distillation. Methanol is an important solvent and is also used as a chemical reagent in the manufacture of such substances as dyes. In its synthesis two gases, carbon monoxide, derived from coal, and hydrogen are employed. The process is similar to that used for the fixation of nitrogen, and costs are reported to be so low as to give the synthetic product a marked advantage over the natural product. Butyl alcohol, a solvent raised to great importance by the development of modern nitrocellulose lacquers such as are now being used on many automobiles, pieces of furniture and even buildings, is still produced principally by the fermentation of corn, but abroad it is made syn-

thetically, and even ethyl alcohol, better known as grain alcohol, is reported to have been synthesized in the laboratory, though not yet produced in commercial quantities.

Most of the examples that have just been cited depend for their synthesis upon catalysts which, though but lately recognized as such in industry, play a vital rôle in most synthetic processes. A catalyst is a substance which, though often used in minute quantities, promotes reactions between other substances at a rate to make them commercial. The catalyst does not appear in the final product, is not itself changed and the exact mechanism of its action is still a question for discussion. It has been described as a chemical parson which unites two elements to form a new group without becoming a part of that group.

Other materials of importance have been synthesized to the great advantage of medicine and surgery. Certain glands, such as the adrenal and thyroid, have been processed for the sake of extracts of great potency. This involved handling enormous quantities of material, the glands of thirty thousand sheep being required to produce one pound of adrenalin. The necessary purification and concentration involves a number of operations which make possible a product more variable in characteristics than is desirable, and expense is always greater where large quantities of raw material must be treated with low yields. This incidentally is one of the reasons why radium is so expensive. The active principles of the adrenal and thyroid glands are now made synthetically, the product being uniform and the prices lower than was possible by the old method. Insulin is another glandular product of which we have heard much in the last few years. Insulin as a pharmaceutical product is passing through the several stages of development and it may be expected that eventually it also will be synthesized.

The flavoring extract manufacturer tells us that vanilla is the most popular flavor in America. Originally made by extraction from Mexican vanilla beans, using alcohol as a solvent, the active principle of this flavor is now prepared from coal tar. It would require the resources of fifty Mexicos to meet the demand for vanilla beans, and without the synthetic product we should be compelled to choose some other flavor or pay an almost prohibitive price.

Lacking such natural resources as we possess in petroleum, the chemists of Europe are striving to synthesize liquid fuels from solid ones. One investigator by treating powdered coal with hydrogen under pressure and at high temperatures has succeeded in an experimental way in converting much of the solid fuel into a liquid one. By using the coal to produce carbon monoxide gas, a synthetic oily liquid has been produced in another laboratory and is looked upon with some favor as a possible supplementary fuel for internal combustion motors.

A synthetic product that is now in great favor is rayon, the man-made silk which not only threatens to become the ultimate successor of natural silk but may ultimately be produced so cheaply as to dethrone King Cotton. Even now the raw materials for a pound of rayon cost little if any more than a pound of raw cotton. When our research laboratories solve the riddle of the constitution of the cellulose molecule—cellulose being the material which makes up wood and cotton, the starting point in rayon manufacture—great improvements may be expected not only in rayon but in many other cellulose products.

It seems unnecessary to remind you that the synthetic products of chemistry most widely advertised and perhaps best known are the synthetic dyestuffs now

obtainable in thousands of colors and shades. Such materials not only have been more satisfactory than most of the animal, vegetable and mineral coloring matters, but afford a range of shade and a fastness of color to light and washing in no wise approached by the natural products.

We smile when we think of the apprehension with which the early English regarded the exhaustion of the yew from which long bows were made for their army. Generations later other Englishmen worried over the shortage of oak for ships' knees, without which the navy could not be maintained. Still later the foremost question in national defense was how to make satisfactory iron without adequate supplies of charcoal, which was growing scarce. In every case, before the expected calamity fell new developments had removed the danger. Thus far science has been able to avert dangers which threatened through the exhaustion of particular natural resources. This does not mean that science invites America to continue to be a spendthrift. Science puts off the time when exhaustion of resources will be upon us by developing better ways of utilizing materials at hand. With the growth of our knowledge of the constitution of the molecule and of the atom of which it is composed, there may come an age of synthesis which will rival in richness and splendor all those which have preceded it.

THE ISOLATION OF ANCIENT AMERICA AS INDICATED BY ITS AGRICULTURE AND LANGUAGES

By Dr. W. E. SAFFORD
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When Columbus and the explorers and colonists who followed him reached America they found that the native Indians, both north and south of the Equator, had developed an agriculture quite distinct from that of any country in the Old World.

In the West Indies they found fields of sweet potatoes and extensive plantations of mandioca, the plant from which cassava and tapioca are derived, growing in long rows and spaced at equal intervals, which called forth expressions of admiration in the reports sent home to Spain. Other cultivated crops were a cereal which at first they compared to millet, with large grains closely packed round a central cob. This was our Indian corn, called *mahiz* or *maize* by the islanders. Other important crops were red peppers, which the islanders called *ahí*, and peanuts, which they called *maní;* and among the fruits was the delicious pineapple, which had been developed by selection from a wild plant with linear bayonet-like leaves armed with marginal spines. Among their potherbs was a plant with enormous leaves, related to our Jack-in-the-pulpit, which in the British West Indies is now called Carib cabbage.

Other important plants of the West Indian Islands were cotton, quite distinct from that of the Old World, and tobacco, a plant unlike anything before seen. In their reports the Spaniards said they "fumigated themselves" with its leaves. This tobacco had undoubtedly been brought, like the sweet potatoes, the cassava plant, the maize, red

pepper, pineapple and Carib cabbage, from the mainland of northern South America, where these crops were also found in cultivation.

The conquistadores who invaded Mexico found the principal food staples of that country to be Indian corn, squashes and beans quite distinct from the well-known *faba*, or bean of Europe. They also found beautiful plantations of the native magueys, or century plants, which the Mexicans had brought into cultivation for the sake of their sugary sap, fermented by them into an intoxicating drink, and that they had improved certain varieties of native prickly pears by cultivation, the fruit of which was so sweet and juicy, although filled with small seeds, that it was introduced into Europe under the name of Indian fig. Another closely allied cactus was the host plant for breeding a certain insect which yielded not silk, like the moths of the Orient, but a beautiful red dye which the Aztecs called cactus blood. This was cochineal, a scale insect allied to that of the Old World yielding the rich crimson with which the curtains of the Ark of the Covenant were dyed.

Perhaps the most important of all the cultivated Mexican plants was the cacao, from which the Aztecs made their chocolate. In certain localities its seeds were used and still are used as money. For flavoring their *chocolatl*, or chocolate, they used the pods of a climbing orchid, which they planted in shaded groves and trained upon the trunks of trees. This was the vanilla, one of our most delightful heritages from ancient Mexico.

In certain localities inhabited by more primitive tribes, sheltered ravines were encountered across which transverse walls of stones had been piled at intervals to retain the soil washed from the plateau above. Each of the terraces thus formed was planted in corn, beans and squashes, and cultivated in a primitive fashion. In Peru were found mountain slopes with miles of irrigated terraces, of which the small ravine dams above described were the prototype. On these terraces and on the coast most of the plants already mentioned were also found in cultivation. The food products of the Peruvian gardens and plantations and imitations of them in the form of pottery funeral vases were interred with their dead. Thousands of specimens of the latter are now to be found in archeological museums of this country and of Europe.[1]

The early colonists of North America found the entire Atlantic coast, from Florida to Canada, inhabited by tribes of Indians who practised agriculture. Their principal crops also were Indian corn, beans, squashes, pumpkins and tobacco. Their tobacco, a yellow-flowered species with stalked leaves, was identical with the *Nicotiana rustica* of the Mexicans and quite distinct from the milder, pink-flowered *Nicotiana tabacum* of the West Indies. The interior valleys of the Mississippi and its tributaries were planted with fields of Indian corn about which twined beans of various kinds and through which trailed the vines of pumpkins and squashes. The Indians cultivated sunflowers for the sake of their rich, oily seeds, and their relative, the Jerusalem artichoke, for its edible tubers. Farther to the westward were tribes which also practised agriculture, including other species of tobacco and in the arid southwest surrounding the pueblos of the Zuñi and Hopi Indians as well as in canyons bordered by cliff dwellings were cultivated patches of corn, beans, squashes and in some places cotton, all of which were probably intrusions from Mexico.

In the agriculture of ancient North America tropical plants requiring more than a year to mature could not possibly

[1] See Safford, W. E., "Food Plants and Textiles of Ancient America," in *Proc. Nineteenth Congr. Americanists*, 12–30, 1917.

become established. All the crops were annuals sensitive to frost, and had to be replanted each year. On account of the severe winters, the tropical fruit trees found in the West Indies and grown in the warm barrancas of Mexico were absent from the fields and villages of our own Indians.

In a previous radio talk[2] I called attention to the fact that the cultivated plants I have enumerated were all developed from wild American plants, long before the time of Columbus: Indian corn from a grass allied to the Mexican *teosinte,* sweet potatoes from a fleshy-rooted morning-glory, beans from twining plants growing in thickets, pumpkins and squashes from trailing gourds, probably bitter and uninviting in their wild state, and the so-called Irish potato from a wild tuber-bearing nightshade of the Andes of Western South America. Not a single cultivated food plant of the Old World had found its way to America—not a grain of wheat or of oats, rye, barley or rice; not a single fruit known in Europe, Asia or Africa.

In ancient Europe the condition was very different. In the gardens and fields of England, as well as on the continent, were many flowers, fruits, vegetables and cereals, which had originally been brought from distant countries, among them oranges (still called *Apfelsinen,* or Chinese apples, by the Germans), lemons, peaches, quinces, pomegranates, melons, cucumbers, watermelons, which had been successfully introduced into cultivation where conditions of climate and soil permitted; and in Egypt an edible arum, the *kulkas,* or Colocasia, identical with the taro of the Polynesians, and seedless Musa, identical with the banana of southern Asia. The histories of some of these plants are lost in antiquity, but the origin of others can be definitely traced. In addition to plants successfully propagated were certain dried products, such as spices, brought from the distant Spice Islands, some of them worth their weight in gold. It was in quest of these that Columbus set out on his eventful voyage. The presence of these exotic plants and plant products in the gardens and markets of Europe was a tangible proof of communication with remote countries at a very early date.

[2] THE SCIENTIFIC MONTHLY, August, 1925, pp. 181–186.

The most celebrated book on the products of distant lands published before the discovery of America was that of Marco Polo, which described many of these imported plants as he had encountered them in their original home. He was the first to give a detailed description of the coconut palm and its fruit, which he called *nux indica,* or Indian nut.

This valuable palm had been spread by human agency in prehistoric times eastward throughout the islands of the tropical Pacific and southwestward to Madagascar.

In the Pacific Ocean the first European navigators found the islanders subsisting principally on well-known cultivated plants of Asiatic origin. Possibly some of you who are listening to-night do not realize the vast area covered by the islands of Polynesia, a great triangle with sides two thousand miles long, with the Hawaiian Islands, New Zealand and Easter Island for its three points, the last, a tiny islet, celebrated for its giant images, so far south of the equator that coconuts and breadfruit will not grow there, but producing taro, bananas and sugar cane bearing names identical with those of Hawaii and New Zealand.

These plants yielded the most important food staples upon which the Polynesians subsisted. They were common to all the island groups and in addition to them were yams which bore the same vernacular name on Easter Island situated in longitude east of the meridian

of Salt Lake City and Madagascar across the Pacific and Indian Oceans, on the coast of Africa.

Taro, the staff of life of the Polynesians, from which the Hawaiians make their paste-like poi, is identical with the kulkas which the ancient Egyptians had received from India; seedless bread fruit, propagated from cuttings or sprouts, and which consequently could have been spread only through human agency, had been known for centuries; and the same is true of their sweet bananas, starchy plantains and sugar cane.

Nearly all the islands of the tropical Pacific were fringed with coconuts, identical with the *nux indica* already referred to as encountered by Marco Polo more than two hundred years before Columbus's first voyage. These palms were propagated from the nuts themselves by the islanders, who distinguished several varieties, some of them valuable for oil or food, others for the fiber of their husks, and others, for their shells, which were used as cups for drinking kava or bottles for containing oil or water. Accompanying the coconuts in nearly every group of islands where they grew were enormous coconut crabs (*Birgus latro*) whose claws are specially modified for feeding on the meat of coconuts. These edible crabs were also associated with the coconut in the islands of the Malay Archipelago and the Indian Ocean. They had probably been brought into the Pacific, like the coconut itself, by the islanders, who highly esteem them for food. Another Asiatic plant was turmeric, so extensively used in the East Indies for making curries.

In addition to food plants the islanders cultivated others of economic importance; as, in Samoa and Tahiti, the paper mulberry, identical with that of China and Japan, from whose inner bark was beaten the filmy tissue composing their tapa or barkcloth. The screw pine, or Pandanus, from which they braided their sleeping mats, was identical with a species held sacred by certain castes in India. It is probable that even some of the larger trees had been propagated from seeds carried by the islanders from their ancient home, among them the kukúi, or candlenut, whose oily kernels strung on a spit served for lighting their huts.

The possession by the Polynesians of these important Asiatic plants indicates southern Asia, or more definitely the Malay Archipelago, as the cradle of the Polynesian race. Indeed most of the plants not only bear the same names in the various island groups, but many of these names are distinctly Malayan. In addition to this fact and equally significant in tracing the origin of the Polynesians is the identity of a great many of their primitive words and grammatical forms with those of the proto-Malayans, inhabiting Sumatra, Java and other islands of the Malay Archipelago. The close resemblance of the Malayo-Polynesian languages points to a comparatively recent dispersal from some common center.[3]

I have spoken thus at length of the Asiatic origin of the food plants of the Polynesians and of the introduction from distant lands of many important European fruits and vegetables, so as to offer a contrast to the agriculture of ancient America, which was built up entirely, as I have already shown, from native wild plants and was quite devoid of a single exotic species. Most of these plants had been in cultivation for many centuries, as shown by their wide distribution and the variations they had undergone in adapting themselves to the conditions of

[3] See Safford, W. E., "Cultivated Plants of Polynesia and their Vernacular Names an Index to the Origin and Migration of the Polynesians," in *Proc. of the Pan-Pacific Scientific Conference* (1920). Special Publ. Bishop Museum 7: 183–187, 1921.

climate and soil. Maize, for instance, had become modified into many varieties, some of which in moist tropical situations grew to an enormous height and sent out roots not only from the base of the stalk, but also from several succeeding nodes; others growing in arid desert regions, waist high, sending down a deep tap root in quest of moisture necessary for their existence.

Beans also had become similarly specialized, some of the varieties having adapted themselves to temperate climates, others to desert conditions and others to the moist tropics. Squashes and pumpkins had developed numerous well-marked forms. Before the coming of Europeans these important food plants had spread northward to the Great Lakes and the St. Lawrence River and southward to southern Chile and Argentina. The development of these food plants from wild species and their specialization into distinct varieties in regions widely separated from one another indicates a very long period of cultivation. Equally significant is the discovery of the properties of such plants as tobacco, cacao, coca, from which cocaine is made, the various narcotic Daturas of North America, Mexico and Peru, and the cinchonas, which yield quinine. A knowledge of their virtues points to many centuries of experience and experiments.

Even more striking evidence of the long presence of man on this continent is offered by the various languages spoken by American Indians, which are segregated into distinct linguistic stocks having little or nothing in common and showing no evidence of Old World affinities. Absurd theories have been advanced from time to time; among them that which suggests that the American Indians are descendants of the lost tribes of Israel, another assuming a Phoenician origin and still another insisting on an affinity between certain tribes and the ancient Welsh. It is scarcely necessary to point out that modern Hebrew closely resembles the language of Israel and that modern Greek has much in common with the language of Homer; much more remarkable are the elements in such widely separated languages as Irish, German, Russian, Latin and Greek, which can be traced back thousands of years to the Sanscrit of India. Were any of the American linguistic stocks even so remotely influenced by an Old World language as that of our own is by the Sanscrit, students of philology would not fail to detect their relationship.

What does all this mean? It means that the tribes from whom the American Indians are descended arrived upon this continent at a very remote time, before the languages of the Old World had taken shape; before Sanskrit was Sanskrit, before Hebrew was Hebrew; before the languages now spoken in China and Mongolia had developed; long before the entrance of the Malayans into the Pacific Ocean.

The agriculture and languages of the New World are as truly American as the turkey, the opossum and the armadillo; or the goldenrod, passion flowers and spiny cactuses. Indeed, the American Indian may be regarded as truly a part of the fauna of the New World as the buffalo; in his primitive state subsisting on the wild animal and vegetable food of his environment; in his more advanced stages on the cultivated plants developed by his own efforts from their wild forms. Certainly the cultivated food crops of America, like the languages of the aboriginal Indians, indicate a very remote antiquity of man in this hemisphere; and the absence of intrusions of Old World plants and of linguistic elements points to his isolation from the time of his arrival until the coming of Columbus.

METHODS OF SEA AND AIR NAVIGATION

By Captain J. P. AULT
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THE art of navigation nowadays is applied to travel in the air as well as to travel over the oceans, where, through improvement and invention, it has been developed to almost an exact science. Much the same problems are confronted and the dangers are very similar for both the airship and for the vessel that sails the seas. Fog and fire, storms and a lee shore offer much the same menace to the pilot in the air as to the deep-water sailor. One tries to keep his ship aloft and to avoid a crash on his lee shore, the ground below, while the other tries to keep his vessel afloat and at a safe distance from the rocky coast line.

The methods of navigation, the means used in determining the ship's position, its latitude north or south of the equator and its longitude east or west of the meridian of Greenwich, are for the most part based on the same elementary principles which have been used since the time of Columbus.

Dead-reckoning, or keeping track of the vessel's direction of travel and of the distance covered from hour to hour, still forms the basis of all navigation. The refinements and improvements have come in perfecting the means for determining the ship's course and speed.

The invention of the magnetic compass about the year 1400 made navigation possible and we still use this same trembling needle to guide our ships through darkness and fog and over the unmarked oceans, even when traveling by airship.

That the compass does not point true north, but always toward the magnetic north pole, was first emphasized during the first voyage of Columbus. When his navigators discovered that the compass was pointing almost 12° to the west of the pole star a near mutiny arose among the sailors, who were already fearful of the outcome of this mad voyage into the unknown, and the discovery of America came near being postponed for many years. Columbus undoubtedly shifted the needle on the compass card, for in the morning the compass again pointed true to the pole star and the doughty admiral explained that the pole star had shifted its position.

Modern navigation charts tell the mariner just how much his compass points east or west of true north, and by allowing for the deviation due to the presence of iron in his ship he can keep a fairly accurate account of his course over the unmarked ocean highways. Improvements in chart-making, in methods of projecting the surface of the earth on maps and the increased accuracy in the position of coast lines and harbors have been great factors in the steady improvement in navigation.

The first radical change in the method of guiding a ship came only a few years ago with the invention of the gyroscopic compass, which indicates true north very exactly, independently of the earth's magnetic field, due to the mechanical effect of the earth's rotation on its axis, upon a rapidly revolving heavy wheel or weight, called a gyroscope. This instrument is particularly useful on ships of war and on large ocean liners, but a magnetic compass is still carried as a check and for use in emergencies.

Owing to the difficulty of mounting a magnetic compass sufficiently far away from the engine and other disturbing influences in an airplane a new instrument called the earth-inductor compass has been developed by the Bureau of Standards for use in aircraft. This device

again makes use of the earth's magnetic field but in a totally different manner from that of the usual horizontal magnetic compass. A coil is rotated in the earth's magnetic field, and the resulting electric current actuates a pointer on the pilot's instrument board. As long as this pointer remains at zero on the scale, the pilot is steering the desired course. This instrument can be mounted out on the wing of the airplane, away from the iron and electric disturbances in the cockpit.

And now we come to the radio compass, the most important contribution to the science of navigation since the invention of the magnetic compass. The captain of a ship, approaching a harbor, can send out a radio signal, and the men at the different radio compass-stations on shore can determine the direction of the incoming signal by slowly rotating the large loop-antennas of their radio-compasses until the signal is loudest. The observers then "radio-wave" back to the captain his bearing or direction from their respective stations. By plotting these bearings on his chart the captain can very quickly and accurately locate his position, and this performance can be repeated as frequently as desirable in spite of fog, clouds or darkness. There are at present about thirty of these stations on the Atlantic coast and more are to be established. Before many years all the harbors as well as all important lighthouses of the world will be equipped with radio-compasses. Accurate bearings may be obtained when the ship is 150 miles offshore, and the method may be used at a distance of one thousand miles if the proper corrections for the curvature of the earth are applied.

Using practically the same principle, a new scheme has been devised for guiding the aircraft pilot between stations. Directional radio signals are sent out between the two stations and as long as the pilot follows the path of these signals a white light is shown on his instrument board. Any deviation in the flight of the airplane to right or left of this path is shown by different colored lights, and the pilot must change his course in the proper way to bring the white light on again. Future improvements and developments in the use of the principle of the radio-compass will go far toward solving the problems of aerial navigation.

For polar work, where the directive force of the earth's magnetic field is very small, owing to nearness of the magnetic pole, the usual magnetic compass is not satisfactory on aircraft and a sun-compass has been devised for use when the sun is shining. This instrument works somewhat on the principle of the sun-dial and the method can be illustrated by taking your watch and pointing the hour hand toward the sun. The approximate north-south direction will be halfway between the hour hand and the 12 o'clock mark on the watch. Since the sun-compass depends upon a knowledge of the airship's position for its indications, any errors in dead-reckoning will introduce errors in the direction as indicated by the sun-compass.

Not only must the course of the ship be known in dead-reckoning the position, but the speed through the water, or through the air, must also be determined in some manner. In olden days they had the chip-log and the hour-glass. The knots in a line were so spaced that their distance apart bore the same ratio to a mile that 28 seconds bears to an hour. The chip would be thrown overboard and the number of knots on the attached line which passed over the rail while the sand was running through the neck of the 28-second sand-glass indicated the ship's speed per hour through the water. And so we have come to call the nautical mile a "knot." In modern times we determine the speed of the vessel by

counting the number of revolutions of the ship's propellor or reading the patent log which indicates the speed directly on a dial connected by a line to a small revolving device trailing along behind the vessel. The air pilot has his ground-speed indicators when the ground is visible, or his smoke bombs or flares if out over the ocean, with which to determine his speed over the ground or over the water.

Owing to uncertain and variable ocean-currents and wind effects, a dead-reckoned position of the ship must be checked up by some other means. Since ships first began to sail the seas, the sun has been used to determine the latitude, a simple computation of the altitude at noon being all that is required. Before the invention of the chronometer-watch about 1761, the longitude was determined very approximately and rather infrequently, I imagine, by long and tedious calculation of measured distances between the moon and various stars and planets, the so-called "lunar distances."

For many years the practice was to sail north or south to the latitude of the place of destination and then sail east or west until land was sighted. Edmund Halley, the famous astronomer, during his voyage on the *Paramour Pink* in 1689–1700 followed this method, and he was as much as three hundred miles out of his reckoning at times. Halley was making the first ocean magnetic-survey, with a view to using the earth's magnetic field as a means for determining the longitude. We owe to him the present-day method of showing on the chart the lines of equal magnetic declination of the compass.

With our high-grade chronometers, corrected daily by means of the radio, a position at sea can be determined very readily and accurately, provided that some celestial object, such as the sun, star or planet, is visible. The exactness of the resulting position will depend upon whether one or more objects can be used. Observations on only one object will tell the navigator that his vessel is located somewhere on a line, the so-called Sumner line. When the navigator measures the altitude of the sun, for example, he may be anywhere on a circle whose center is the point on the earth immediately below the sun and whose radius is equal to the zenith distance of the sun, or 90 degrees minus the measured altitude. A dozen navigators scattered anywhere on this circle, thousands of miles apart, would all get the same altitude of the sun at the same instant of time. For example, if you want to tie a ribbon a mile long to the top of the Washington monument in Washington and then circle around it like a May-pole, stopping every once in a while to measure the altitude of the top, you will find that you will get about 6 degrees wherever you try it. While you are crossing the Potomac River on your circular path, suppose you stop to measure the altitude and to locate your position, then you know that you are somewhere on a very short segment of this circle, and this segment, for all practical purposes, you can consider to be a straight line, at right angles to the direction of the monument. So the navigator who measures the altitude of the sun or star knows only that he is somewhere on a line which is at right angles to the bearing of the object observed and which is not often more than thirty miles long, due to the accuracy of his dead-reckoned position. This line is called the Sumner line, after the American navigator, Captain Thomas H. Sumner, who discovered the method in 1847 and which is the basis of all modern navigation where astronomical methods are used, both at sea and in the air.

It is seen that one line is not sufficient to completely fix the position of the vessel, so another line is necessary, either

from observations on another star or planet or the navigator can observe the sun again after an interval of a few hours, if conditions are right, and the intersection of any two lines completely fixes the position. Venus is often used with the sun for this purpose during the daytime and occasionally even Jupiter.

The new acoustic sounding device is being found increasingly useful in advising the navigator of his approach to land and to assist in determining the position at sea. A sound wave is sent into the water from the bottom of the vessel and a precise measurement of the time it takes for the sound to reach the ocean bottom and to be reflected back again to the ship gives the depth of the water. This depth is shown continuously and automatically on a dial on the navigator's bridge, and this gives immediate warning of approach to shore.

Many improvements have been made in instruments, charts and methods of navigation, notably by Maury, Marc Saint Hilaire, Aquino, Littlehales and others, so that at present a determination of a ship's position involves very little calculation.

Just as the use of astronomical methods came to the aid of dead-reckoning, so radio is now completely revolutionizing the older methods in the science of navigation and the radio future will witness vessels of the sea and ships of the air sailing along confident of their position in spite of uncertain winds and of unknown ocean currents, in spite of fogs and of sunless days or starless nights.

MECHANICAL REFRIGERATION

By Dr. W. E. TISDALE
NATIONAL RESEARCH COUNCIL

SUMMER follows winter with such regularity that it might seem, especially to dealers in ice, that there would never be any question as to a market for their product, and indeed it is probable there will never come a time when we shall cease to need refrigeration processes for the preservation of foodstuff, but the handwriting on the wall seems to indicate that the use of ice in homes as a means of refrigeration will soon become obsolete. The office of a refrigerator or cooling chamber is to prevent the growth of microbes which are perhaps best known to you in three different groups—the molds, such as grow on bread and on fruit—especially when the skin is broken; the yeasts, whose principal action is to cause fermentation; and bacteria, which, through their activity, produce disintegration of foodstuffs and cause such familiar poisonings as the ptomains.

Refrigerating temperatures, as ordinarily used in the preservation of foods, do not kill these objectionable organisms but rather keep them in a quiescent state and prevent their growth. These organisms which tend to destroy food will not multiply to any extent at temperatures under 45 degrees Fahrenheit, and a proper refrigerating temperature should therefore be between this temperature and a few degrees below the freezing point of water.

It is possible to install refrigerating machinery in many of the old style ice refrigerators, but manufacturers of this equipment are reluctant to do so for the reason that most ice refrigerators have

a very low efficiency due to improper insulation. Every known substance conducts heat to a certain extent, but so-called dead air perhaps conducts it less than any other common material. A porous substance, such as cork or a very spongy rubber, is filled with minute air bubbles and serves excellently as insulation between the inner and outer walls of a refrigerator. Unless refrigerators are properly insulated, there is a large waste due to the flow of heat from the outside to the inside. If, then, a dealer in high-grade refrigerating machinery refuses to install his equipment in your old ice box, you can be assured that the prime reason is the rendering of real service to you.

In differentiating between the different types of refrigerating machines, it will be necessary to observe the general physical processes which they employ. As a beginning, we are reminded that matter, as we know it, exists in three states—as a solid, as a liquid, or as a gas. In all three states the molecules are in motion and the vigorousness of their motion depends upon the amount of heat they contain, or, in other words, is a function of their temperature. In solids, the molecules are so closely packed that they are much restricted in their vibrations and their interactions are so strong that they remain relatively fixed. In liquids, the molecules are further apart but are still close enough together to have interactions, as evidenced by the slowness with which thick oils flow. Liquids have a surface and take the shape of the containing vessel. In gases, the molecules are so far apart that they have no adherence to each other; their vibration paths are relatively long; they wander all through the space in which they are contained; and because of their collisions with each other and with the walls of the containing vessel, they exert a pressure on these walls.

We can therefore picture what happens in a solid when heat is applied to it. The molecules get further and further apart—as evidenced by their expansion, until finally they are so far apart that they no longer remain in a given form, but need a wall to restrain them from flowing, and thus become liquids. When a liquid is heated the molecules are pushed further and further apart—as again evidenced by expansion—and many of them at the surface get so far away that they do not return, because of interaction. When these molecules leave the surface of a liquid the process is called evaporation. Certain conditions of evaporation are defined as boiling, and the temperature at which a liquid boils depends upon the pressure of the vapor above it—a low pressure of vapor permitting boiling at a lower temperature than will be permitted by a higher pressure of vapor.

Water is very familiar to you in these three states—solid, liquid and gas—and you know it as ice, water and steam. Let us consider a block of ice at a temperature below its freezing point. If heat is applied, it will expand and its temperature will rise until it reaches, on the Fahrenheit scale, 32 degrees. Continuing the supply of heat the ice will gradually melt, but the mixture of ice and water will remain at this same temperature, 32 degrees Fahrenheit, until all the ice is melted. The heat which is necessary to change ice to water, therefore, does not appear as a temperature effect. It is quite evidently a latent heat and is known to those who are concerned with such studies as the latent heat of fusion. After the ice has all melted, further heating of the water will cause it to expand, and its temperature will gradually increase until it begins to boil. As long as the water and the steam are in contact and the pressure is not increased above that equivalent to one at-

mosphere, the temperature of the water will not increase above 212 degrees Fahrenheit. Here again there is a quantity of heat necessary to change the state of a substance—from a liquid into a vapor —and it is known as the latent heat of vaporization. Obviously, if it requires heat to melt the solid and to vaporize the liquid, it can readily be conceived that if a vapor is liquefied or if a liquid is frozen heat will be liberated. Because liquids and gases are easily transferred through pipes, refrigerating machines use them rather than solids as refrigerants, but they all make use of this latent heat involved in the change of state, although they do not necessarily use water as the refrigerant for the reason that it boils at too high a temperature. It is generally much more conveninent to use some substance which boils at or below refrigerating temperatures. Obviously, a liquid which does boil at as low a temperature as 45 degrees will not be found in any quantities in nature because it would have boiled away under ordinary outdoor temperatures. Such refrigerants, therefore, are usually manufactured, and ammonia, carbon dioxide, sulphur dioxide, ethyl chloride and methyl chloride are the most common ones. They are expensive, and systems employing them do not permit the vapor to escape in the air, but by their process condense it and revaporize it over and over again.

You will, of course, understand that there is physically no such thing as cold. A space is cold because of the absence of heat and our refrigerating devices are therefore devices to remove heat from a given space. In applying physical principles to the process of refrigeration, several distinct methods are employed, but in general, they all utilize electrical devices for power and regulation.

Compression System

The compression system of producing refrigeration temperatures utilizes a substance such as ammonia (which boils at 33° below zero) and provides a chamber or coil in which rapid evaporation or boiling takes place, together with a pump which will compress the vapor sufficiently to liquefy it. Heat must be supplied to the refrigerant in order to cause it to evaporate or boil, and this is supplied by the air in the refrigerator which, even at zero, contains sufficient heat for this purpose. The abstraction of the heat supplied to the refrigerant causes the air in the refrigerator to cool and this heat, becoming latent in the refrigerant vapor, is carried to the compression chamber. As the pump compresses the vapor to the point of liquefaction, this latent heat again becomes apparent heat in the newly compressed liquid. This newly compressed liquid is cooled by means of circulating water or air surrounding the compression chamber before it is caused to return to the refrigeration chamber, where the cycle begins anew. With the aid of thermostatic control of proper devices, the operation is made automatic.

Absorption System

Refrigerating devices employing the absorption system depend for their operation upon the fact that certain material will absorb or dissolve a large volume of gas. Water at 56 degrees Fahrenheit will absorb or dissolve eleven hundred times its volume of ammonia gas. The rapid absorption of the vapor of the refrigerant causes rapid evaporation—the heat being supplied by the air of the refrigerator. The material which has dissolved the refrigerant vapor must be heated to drive off the vapor, and the vapor must be compressed to a liquid

and cooled as in the compression system of refrigeration.

There has recently appeared on the market a new chemical product in solid form, which has the property of absorbing a considerable volume of water vapor. By its use in a refrigerating device water, under reduced pressure, can be used as the refrigerant, thus avoiding the necessity for a compression pump, because the vapor, when driven off from this substance, can be liquefied by simple cooling. All the devices, however, using the adsorption or absorption system in refrigeration are subject to the criticism that a considerable quantity of heat must be used in driving the vapor from the material which absorbed it and a subsequent cooling of this material.

Air Systems

When a gas or vapor has been compressed and is permitted to expand against a resistance, it does a certain amount of work, and in the process loses heat and therefore becomes cooler. Taking advantage of this physical phenomena, machines are built which compress air up to several thousand pounds pressure per square inch and permit it to expand against a moving piston. In this expansion process the air is cooled and if, after compression and before expansion, the gas is cooled by surrounding it with a water jacket, it is possible to produce a temperature so low that a certain small part of the air will liquefy upon expansion. This is the process used in producing liquid air and liquids from other low boiling-point substances. The process is complicated because it requires a very high pressure pump together with another motor or pump to permit the expansion of the gas against pressure. This system is not employed to any extent for small scale production of refrigerating temperatures.

Vacuum System

Vacuum machines permit the use of ordinary liquids, such as water, which are made to boil by reducing the vapor pressure over them. These refrigerants, being liquid at ordinary temperatures and pressures, are easy to obtain and transport, and have none or very few of the disadvantages of gas refrigerants. They are easy to condense, requiring but little pressure to liquefy their vapors. A very low vacuum must be maintained, however, and for this reason there is much trouble from air leaks into the system. There is considerable promise from this type of refrigerating device, because with proper machine design and a selected refrigerant only moderate volumes of vapor need to be pumped, and the machine may be small.

Vapair System

The Vapair process combines some of the advantages of the vacuum and air systems into one system. A vacuum pump reduces the vapor pressure over a liquid refrigerant and at the same time compresses the residual air in the system and allows it to expand through the liquid. The air in expanding or being violently blown through the liquid does work on it in greatly extending its surface, which markedly increases the amount of evaporation above that possible by vacuum alone. The action of the vacuum pump in rapidly removing this mixture of vapor and air suggests the name Vapair, by which the process is known. This type of device eliminates the expansion motor required in the air machines and eliminates some of the trouble from leaks experienced in vacuum machines where higher vacua are required. The Vapair system involves several fundamentally new principles of thermodynamics.

A NEW PRINCIPLE IN RADIO REPRODUCTION

By Dr. LEE DE FOREST

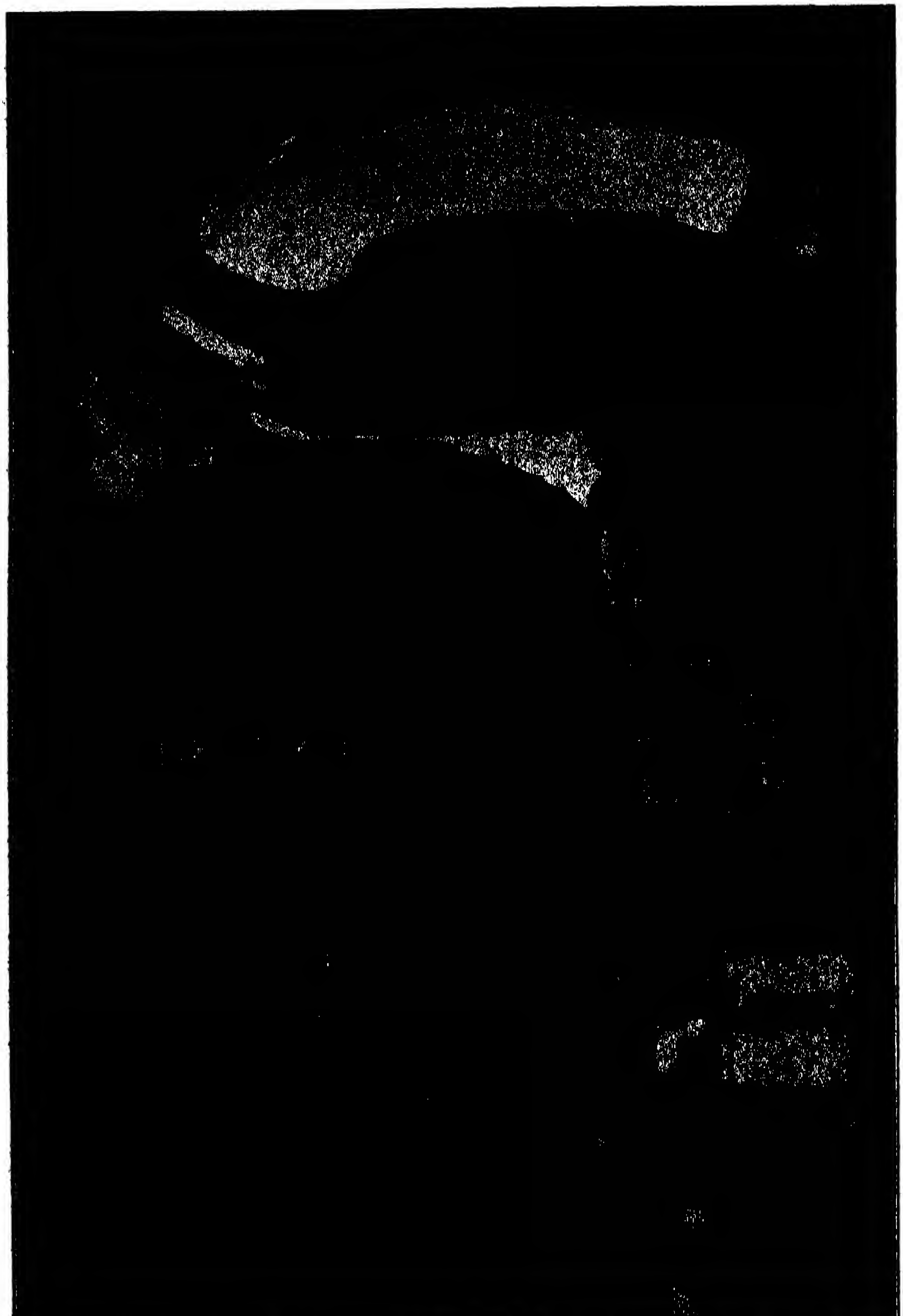
NEW YORK

SINCE the days of the first telephone receiver of Bell, every practical telephone reproducer has been operated on the same general principle, that is, by moving a diaphragm or some form of membrane in the direction perpendicular to its surface. It seems that telephone engineers have been unable to get away from the idea that a medium which produces sound waves must work like a piston. While this method has proven quite satisfactory so long as applied to ear-phones, it has certain inherent defects which become apparent when a larger body of air is agitated, as in the case of a loud speaker.

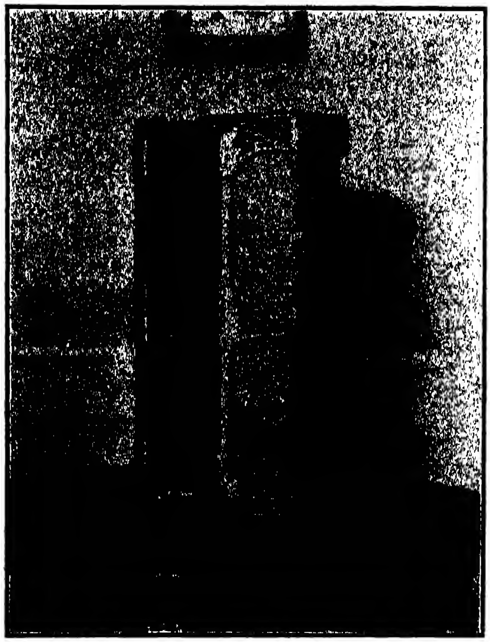
When used in connection with the Phonofilm, or talking moving picture, these defects of the diaphragm piston-action are quite objectionable. The successful presentation of the Phonofilm requires that a large theater be filled with sound of uniform volume without objectionable intensity in any location. The reproduction, of course, must be perfectly natural so that the audience will not have to exert conscious effort in order to understand what is being said. Furthermore, the reproducer must be free from directional qualities so that the audience will concentrate attention upon the screen and thus gain the illusion that words are coming from the lips of the actors rather than from some adjacent source.

Loud speakers of the diaphragm and horn type are unsuited for use in theaters and large auditoriums, owing in part to the fact that such speakers project their primary sound energy into a space of approximately the form of a cone, with waves of maximum amplitude along the axis, while the diaphragm itself forms the truncated apex. Attempts to produce sufficient volume outside of this conical limit, as is necessary to supply the side rows of a theater, result in objectionable intensity nearer the apex, or in the middle front seats. The line of maximum amplitude along the axis produces a distinct directional effect, making the source of sound easily detected by aural triangulation. Furthermore, the piston impact creates impure waves or distortion, which impair the naturalness of reproduction. Even a large number of speakers placed across the stage produce the same results, each individual in the audience tracing the source of sound to the particular speaker which transmits to him the predominant energy.

In seeking a solution for this baffling problem, I felt compelled to abandon diaphragm reproducers of both the cone and horn types, and as a result discovered an entirely new principle of sound reproduction which avoided all the defects mentioned above. In this new method I found that when an electromagnetic telephone unit is applied tangentially to the edge of a properly curved membrane, instead of at right angles to it, the entire surface takes up the vibrations in a gentle whipping or rolling action and sends out sound waves of the correct amplitude in all directions. Many of these waves are projected radially by the displacement of the membrane normal to its surface, but the



DR. LEE DE FOREST
EXPERIMENTING IN HIS LABORATORY ON THE AUDALION



THE AUDALION

predominant action seems to be due to either the rolling or the frictional effect which transmits waves tangentially. This is shown by the fact that the maximum sound energy is propagated from the area of the membrane which has the least radial displacement and the greatest circumferential motion, as the portion near the edge to which the tangential impulses are applied.

It was found that the maximum efficiency is obtained when the membrane is approximately cylindrical or a section of a cylinder; but a true circular contour is not satisfactory because it imposes a variety of stresses which results in distortion due to creating natural periods of dissonant vibrations. The membrane must be permitted to assume a particular horseshoe form, or more specifically, a catenary, and there must be an opening in the back so as to avoid resonance, or the "barrel tone."

The distinctive characteristics of this new form of wave action are extreme clarity and naturalness of reproduction, and the ability to fill a large room with uniform volume without objectionable intensity nearby or in any one direction. This may be explained by the fact that a larger section of air receives the primary impulses at a uniform amplitude and in all directions simultaneously, thus avoiding certain interferences and the necessity of readjusting the wave action after it has been propagated. In other words, each impulse travels in a straight line from the membrane to the hearer without dissipating its energy in adjacent sound voids as represented by the space in the rear of a horn type speaker. The increased carrying power without intensity is due to the larger source of energy with less concentration per unit of cross-section.

At first I constructed two models of the Audalion, as this new reproducer is called, a large one for theater work and a smaller size for radio use in the home. But I found that the smaller size was

equally efficient in the theater, owing to its wonderful carrying power and distributive qualities. The actuating unit, which is of the balanced armature type, is extremely sensitive both to the lowest musical note and to the highest audible overtones. This sensitiveness is essential to the faithful reproduction of the individual instruments of an orchestra in their natural timbre, but it also necessitates good broadcast reception, for a reproducer can not make up for the deficiencies of the receiver. Radio is rapidly approaching a high degree of efficiency, however, and both receiver and reproducer must contribute their share. Furthermore, the public is demanding better equipment, and as the mystery of radio wears off, people are learning the importance of careful tuning and the proper care of batteries.

An interesting psychological reaction has been observed in the introduction of the Audalion. Probably the most beautiful masterpiece of Beethoven would receive scant appreciation from primitive peoples whose weird chants have profound emotional and even religious significance to them. Likewise, modern jazz, which has such strange effects upon our younger generation, receives little commendation from the older folks whose tastes run more to the dreamy waltz. The confirmed radio enthusiast has become accustomed to the "horn-tone" of reproduction, which he is prone to call "fullness" and "blending." When he hears clear and natural reproduction, therefore, something seems to be lacking. On the other hand, the trained musician who has had pronounced aversion to radio reproduction, or "canned" music of any kind, readily appreciates this new style of reproduction for the very reason that it avoids the added resonance to which he has objected. These comparisons merely show that so far as music is concerned, at least, we prefer that to which we are accustomed. But since the public is becoming more discriminating every day, it seems safe to predict that in the long run the best quality of reproduction will prevail.

ELECTRICAL PHONOGRAPH RECORDING

By JOSEPH P. MAXFIELD

BELL TELEPHONE LABORATORIES, INC.

The history of the development of nearly all the technical arts has shown that from time to time the progress of the art has received an impetus through the adoption of some new principle. In the periods between these advances take place the improvements in details which result in the new principle being applied to the best commercial advantage.

This has been so in the talking machine art. Early in its development, the introduction of a duplicating process by means of which large numbers of records on long-wearing material could be made from a first impression on soft wax allowed the talking machine field to be exploited commercially. Then the development of a smooth-running motor-driven machine in place of the early hand-operated ones opened up a field of higher class music.

The method of recording with which this paper deals represents the outcome of the application of new principles to the phonograph art. These new principles have been largely borrowed from the results of research on telephone circuits. As is well known, analogies between mechanical and electrical circuits have been used in the teaching of electricity for some years. However, in the field of application, particularly in the communication art, problems of wave transmission in electric circuits have been very completely worked out. When a survey of the talking machine problem was made, it was early realized that most of the problems were of a wave transmission character and the work was greatly aided by reversing the use of the analogies between the mechanical and the electrical circuits to give an explanation of the behavior of mechanical systems in terms of known electrical systems.

Before considering the methods involved, it may be well to make a rough division of the problem into its component parts. The storing or recording of sound requires first a mechanical system which will respond faithfully to the sound waves which are to be recorded. Then there is required some material in or on which this sound may be recorded and an intervening system which permits the sound waves to make the record in this material. In the usual case, and in that with which we are particularly concerned here, there is a mechanical system which will vibrate in response to the sound which is to be recorded and directly through some mechanical linkage or less directly through electrical equipment drive a cutting stylus which will impress a wax record.

The first consideration, therefore, is the character of the sound which is to be recorded, including all the effects of reverberation and the general questions of studio design. Next to be considered is the manner in which the cutting instrument shall impress this speech or musical record upon the constantly rotating wax disc, which disc is commonly called the wax master. In this connection, there will be discussed also the relative value of the electrical and mechanical linking of the cutting knife with

Some of the Principal Workers on the Problem of Electrical Phonograph Recording. To the left, J. P. Maxfield, in charge of the work; in the center, S. S. A. Watkins, responsible for adapting the equipment to commercial uses; on the right, H. C. Harrison, contributor of most of the fundamental ideas concerned in the development of the recorder; next to Mr. Harrison is A. T. Taylor, expert in the assembly, adjustment and care of the recorders, and next to Mr. Watkins, A. C. Millard, expert in care and control of the amplifier equipment.

the mechanism which receives the sound waves.

In recording work, therefore, one of the important factors deals with the acoustics of the room in which the recording is done. It is probable that the most comprehensive single factor in this connection is the time of reverberation, *i.e.*, the time taken for a sound of given intensity to die away after the source has been stopped. Experiment has shown, however, that the shape of the room and the position in which the curtains and other absorbing materials are hung play a part in the excellence of the music. By a proper control of the acoustic properties of the recording room, it has been possible to record the so-called "atmosphere" surrounding the music. When this result has been accomplished, the listener seems to "feel" the presence of the artists to whose record he is listening.

If a studio is too highly damped or, as a musician would say, "too dead," all the instruments lack the vibrant, ringing tone to which we are all accustomed and which lends life and spirit to the music. The impression on the listener is very similar to that produced by music played in the open air where no floor or sounding boards are provided to reflect the sound. If a room is insufficiently damped, or in the musician's terminology "too live," two effects are produced, both of which are disagreeable. The first is a tendency of one set of notes to blur with those produced immediately before and after, and in the case of large orchestras the blurring is so bad as to make it impossible to pick one instrument from another. The second effect is to leave the listener with the impression that he is listening to music being played in a totally bare and empty room. It is interesting in this connection that the studio must be slightly more damped than the rooms in which we are accustomed to listen to music, because the phonographic process is what we call single channel, that is, it "listens" with "one ear" only. The effect of slightly too live a room can be imitated by any one by stopping up one ear and listening with the other one alone. When the acoustic conditions are correct, the illusion produced is so good that the reproduction is raised from the class of minor amusement to that of an artistic production.

In the case of large orchestras and similar types of music, the reverberations in the hall or theater constitute part of the musical and artistic effect. The solution of the problem of recording these effects in such a manner that when the music is reproduced in a living room the effects appear to be those desired has constituted one of the real advances in the recording art.

The second important factor is the range of notes or frequencies which it is possible to record and reproduce. The range of notes or frequencies which occur in speech and music, particularly where all types of music, including such instruments as the pipe organ, are concerned is from about sixteen cycles per second to approximately ten thousand. It has been found, however, that very acceptable reproduction of most types of music, and of speech, can be obtained by faithfully reproducing the band of notes starting about two octaves below middle C and including up to approximately one half octave above the top note of the piano.

In this connection, it should be made clear that a reproducing system which fails to reproduce all frequencies below, let us say, middle C will, nevertheless, reproduce the auditory sensation of a musical note whose fundamental is below this, even though the fundamental and one or two of its harmonics have been eliminated in the reproduction. While this elimination of the lower components in no way changes the apparent pitch of the note, it does change what is commonly called the "character" or

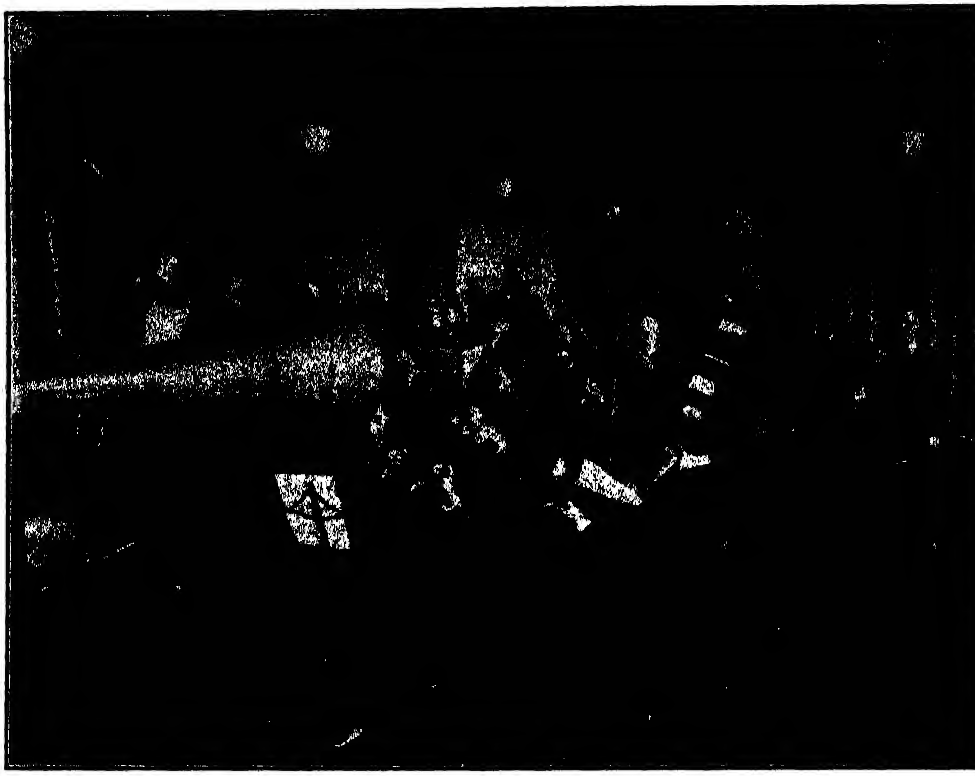


FIG. 1. PICTURE OF AN ORCHESTRA RECORDING FOR THE ACOUSTIC PROCESS. THIS PICTURE WAS FURNISHED THROUGH THE COURTESY OF THE VICTOR TALKING MACHINE COMPANY, CAMDEN, NEW JERSEY AND THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

"timbre" of the note. The "metallic" quality of tone characteristic of the older type talking machine was largely brought about by the failure to reproduce these lower tones.

In attacking the problem of improved recording methods there are two obvious lines of procedure. The first is to make use of the energy of the sound waves for the purpose of operating the recording instrument. This is the method which has been in use for many years. The second is to make use of high quality electrical apparatus associated with vacuum tube amplifiers in order to give more freedom to the control of the process. This second method has been adopted because the amount of the energy available directly from the sound to be recorded is so small as to make its use extremely difficult, particularly if the artists are to play or sing in a natural manner.

Figures 1 and 2[1] show, respectively, a group of artists recording by the old method and the same group recording by means of the electric process. It will be noticed in Figure 1 that the artists are grouped very closely about the horn. In the case of the weaker instruments, such as the violins, it has been possible to use only two of standard construction. The rest of the violins are of the type known as the "Stroh," which

[1] They will appear in the Proceedings of the institute with a paper to be read at the midwinter convention.

FIG. 2. PICTURE OF THE SAME ORCHESTRA SHOWN IN FIG. 1, BUT RECORDING FOR THE ELECTRIC PROCESS. THIS PICTURE WAS FURNISHED THROUGH THE COURTESY OF THE VICTOR TALKING MACHINE COMPANY, CAMDEN, NEW JERSEY AND THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

is a device strung in the manner of a violin but so arranged that the bridge vibrates a diaphragm attached to a horn. This horn is directed toward the recording horn, as shown by the player in the foreground. With such an arrangement of musicians, it is very difficult to arouse the spontaneous enthusiasm which is necessary for the production of really artistic music.

In Figure 2 the musicians are sitting at ease more nearly in their usual arrangement and all are using the instruments which they would use were they playing at a concert. Furthermore, the microphone is now sufficiently far away from the orchestra to receive the sound in much the manner that the ears of a listener in the audience would receive it. In other words, it picks up the sound after it has been properly blended with the reflections from the walls of the room. It is in this way that the so-called "atmosphere" or "room-tone" is obtained.

In the old process it sometimes happened that after the instruments had been arranged in such a manner that the relative loudness of the various parts had been balanced correctly, it was found that the whole selection was either too loud or too weak. This usually meant a complete rearrangement of the players. With the flexibility introduced by the use of electrical apparatus including amplifiers (see Figure 3), the control of loudness is obtained by simple manipulation of the amplifier system and is in no way related to the difficulties of the relative loudness of one instrument to another. The only problem for the studio director in this case is to obtain the proper balance among the various musical instruments and artists. The

FIG. 3. THIS FIGURE SHOWS AN OPERATOR MANIPULATING THE AMPLIFIER SYSTEM TO OBTAIN THE CORRECT LOUDNESS. THIS PICTURE WAS FURNISHED THROUGH THE COURTESY OF THE COLUMBIA PHONOGRAPH COMPANY, NEW YORK CITY.

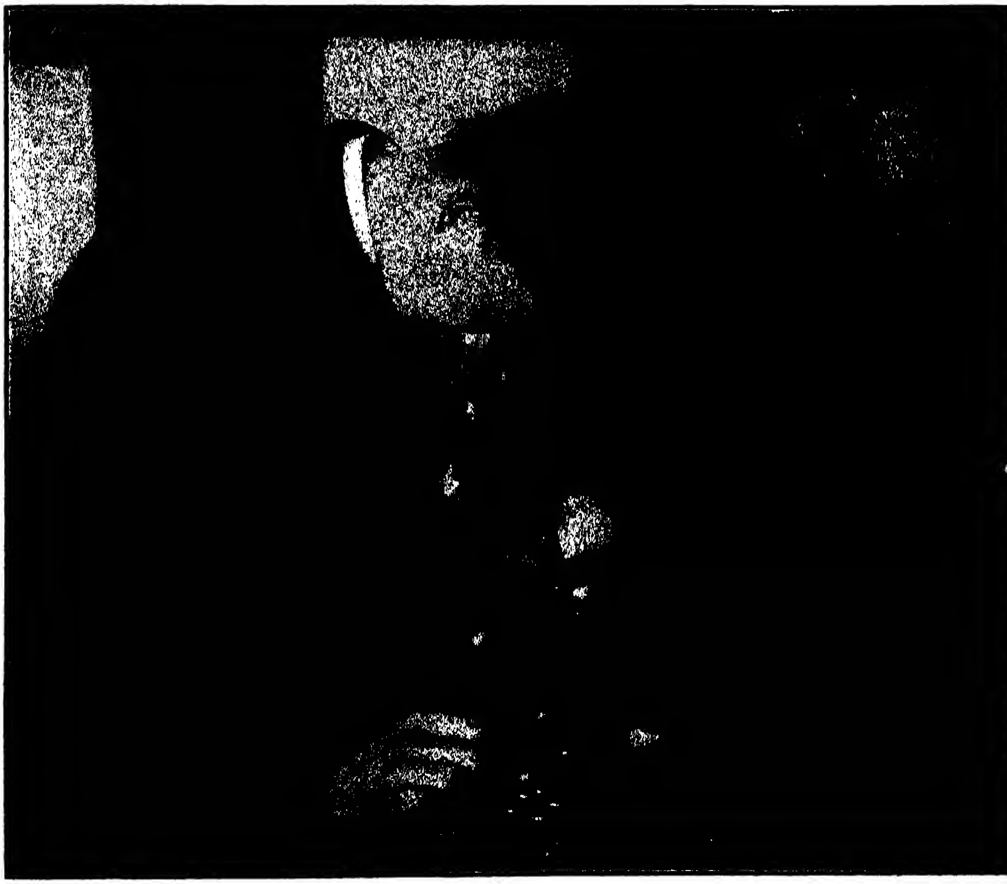


FIG. 4. A RECORDER IN PROCESS OF CALIBRATION BY MR. H. A. SUMMERS.

advantages derived from this added ease of control are also made manifest in that it is much easier and less tiresome for the artists and it is usually possible to make more records in a given time.

It may be interesting to follow the course of the sound vibrations, from the time they are produced until they appear as an irregular groove on the phonograph record. The sound is first picked from the air by means of a spe-

FIG. 5. THIS FIGURE SHOWS AN ELECTROMAGNETIC RECORDER COMPLETE EXCEPT FOR THE BOTTOM OF THE CASE.

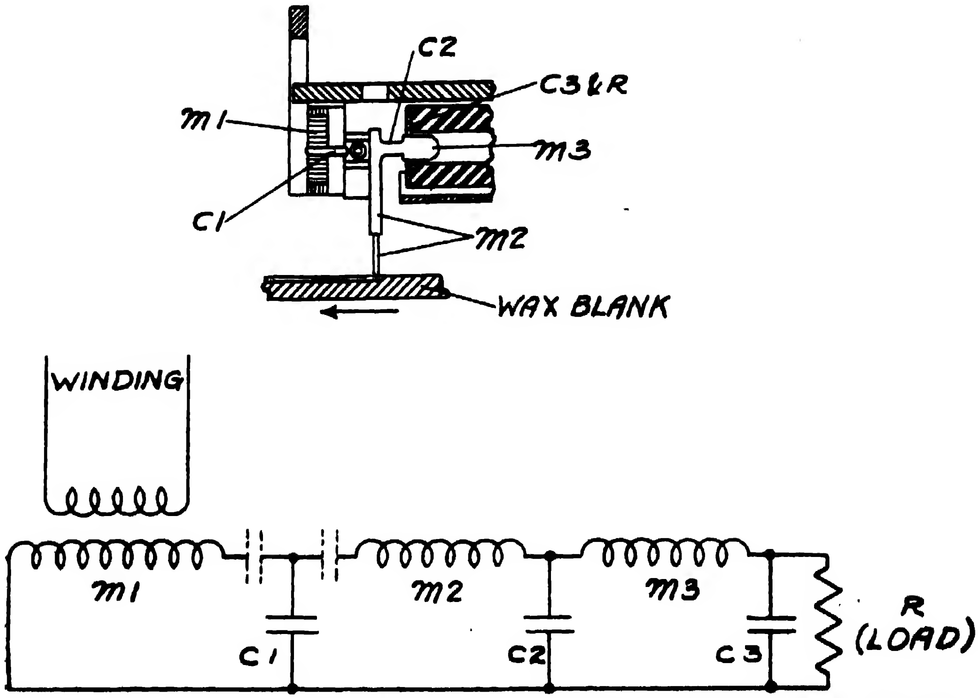


FIG. 6. THIS FIGURE SHOWS, ABOVE, A DIAGRAMMATIC SKETCH OF THE RECORDER MECHANISM AND, BELOW, THE SIMPLIFIED EQUIVALENT ELECTRIC CIRCUIT OF THE SAME INSTRUMENT.

cial telephone transmitter which is essentially an instrument which translates into voltage fluctuations the air pressure fluctuations which strike its diaphragm. These voltage fluctuations, which are exceedingly small, are amplified by distortionless vacuum tube amplifiers until they are of sufficient power to operate the device which cuts the permanent record in the disc of soft wax. This instrument, known as the recorder, is one of the examples of the application of the wave transmission theory of electric circuits to mechanical systems.

A picture of one of these recording instruments is shown in Figure 5, while a simplified diagram of its equivalent electric circuit is shown in Figure 6. In actual practice it has been necessary to take account of some second order factors which have been left out of this diagram as they greatly increase the complexity.

Referring to Figure 6, the inductance labeled m_1 represents the mass of the armature which when acted on by the magnetic field forms the driving portion of the mechanical system. The condenser c_1 represents the flexibility of the shaft connecting the armature to the stylus holder, m_2 represents the mass of the stylus holder and stylus, c_2 the flexibility of the shaft connecting the stylus holder with the metal piece which fits into the rubber damping element, m_3 the mass of this metal piece, and c_3 and r represent the characteristic of the damping element. The two condensers shown dotted and unlabeled represent two of the second order factors which were mentioned above.

Those who are at all familiar with electrical filter design will immediately see that this is a filter of the low pass type, providing the two undesignated condensers are omitted. In this particular case the filter has three sections and a terminating resistance. In designing mechanical analogues of such a system, the problem presented is threefold—

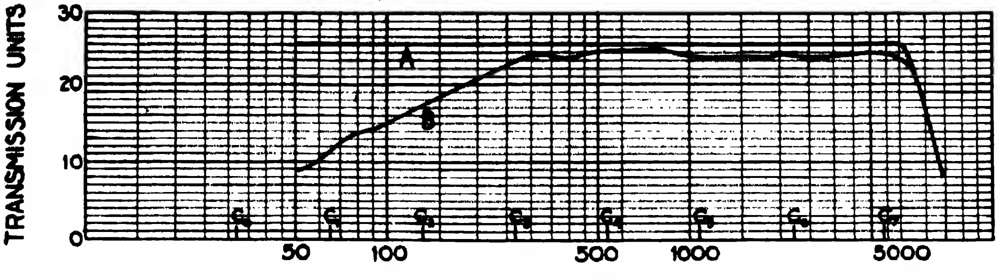


FIG. 7. CURVE A SHOWS THE RESPONSE, THAT IS, CURRENT IN THE SERIES BRANCHES OF A LOW PASS FILTER AS A FUNCTION OF PITCH. CURVE B SHOWS A CALIBRATION OF ONE OF THE RECORDING INSTRUMENTS.

first, that of arranging the parts such that they form repeated filter sections; second, determining the magnitudes of these parts so that the separate sections all have the same characteristics; third, that of providing the proper resistance termination.

The use of the third section and the terminating resistance was decided upon after a considerable amount of experimental work. It was hoped that the resistance of the wax to the back and forth motion of the cutting stylus might be used as the terminating resistance. It was found, however, that under the conditions existing in a commercial recording room, the value of this resistance, even if it were of the correct character, varied so greatly from one wax blank to another as to be unsuitable for the purpose. It is probable also that the value of this resistance is not the same for all notes or pitches lying within the range which it is desirable to record. In the recorder as finally developed, this terminating resistance has been made so large that effect of the wax is negligible in comparison. It acts, therefore, as practically the complete control element of the mechanical filter.

Such a filter when properly designed will have a response *vs.* pitch characteristic of the type shown in Curve A, Figure 7. The actual recorder, however, owing to the presence of the two undesignated condensers of Figure 6, has a loss of response at the low pitch end. This loss is unfortunately necessary in order to avoid the large amplitudes which accompany the low pitched notes and which would cause the trace on the record to cut from one groove over into its neighbor. Curve B of Figure 7 shows an actual calibration of a recorder. While we have no accurate calibration of the older processes of recording, there is considerable evidence to indicate that the fundamentals of notes below middle C were not appreciably recorded and that fundamentals or harmonics lying above the middle of the upper octave on the piano also failed to record. The loss of the fundamentals of the low notes was largely responsible for the metallic tones which accompanied phonographic reproduction, while the loss of the higher harmonics was responsible for the general muffled quality and the inability to hear the sybilants of speech. In other words, the low range is responsible for the naturalness or what is termed the "body" of the music, while the higher harmonics are largely responsible for the detail and clarity of the tone.

When a sufficient range of notes is properly reproduced in conjunction with the proper amount of reverberation effect, it is easy for the listener to imagine himself actually present at the original performance.

It is not sufficient, however, to make improvements of the type described in the records alone. Unless the reproducing machine, that is, the phonograph, is capable of reproducing this full range of notes with little or no distortion, no very marked improvement would be noticed when employing the new type instead of the older type of records. A machine fulfilling these requirements has been developed.

ALFRED NOBEL

THE PROGRESS OF SCIENCE

HEALTH FROM ULTRA-VIOLET RAYS

By Dr. Edwin E. Slosson
Director, Science Service, Washington

Dr. Leonard Hill, director of the National Institute of Medical Research, London, and the leading British authority on heliotherapy, says that to get the full effect of the life-giving rays of the sun, a woman should leave her neck and arms bare, and should wear a short skirt and synthetic silk stockings.

Seems to me I have seen a costume like that somewhere recently, worn by somebody who had never heard of Hill and couldn't tell ultra-violet rays from infra-red. That is the nice thing about science. After a custom has been established, in spite of popular opposition and natural conservatism, the scientists come along and prove the rationality of it. As it is the business of philosophy to provide reasons for what we want to do, so it is the business of science to provide reasons for what we are already doing. Crops were rotated to maintain fertility and baseballs were rotated to prevent the batter hitting them, long before scientists explained why it worked.

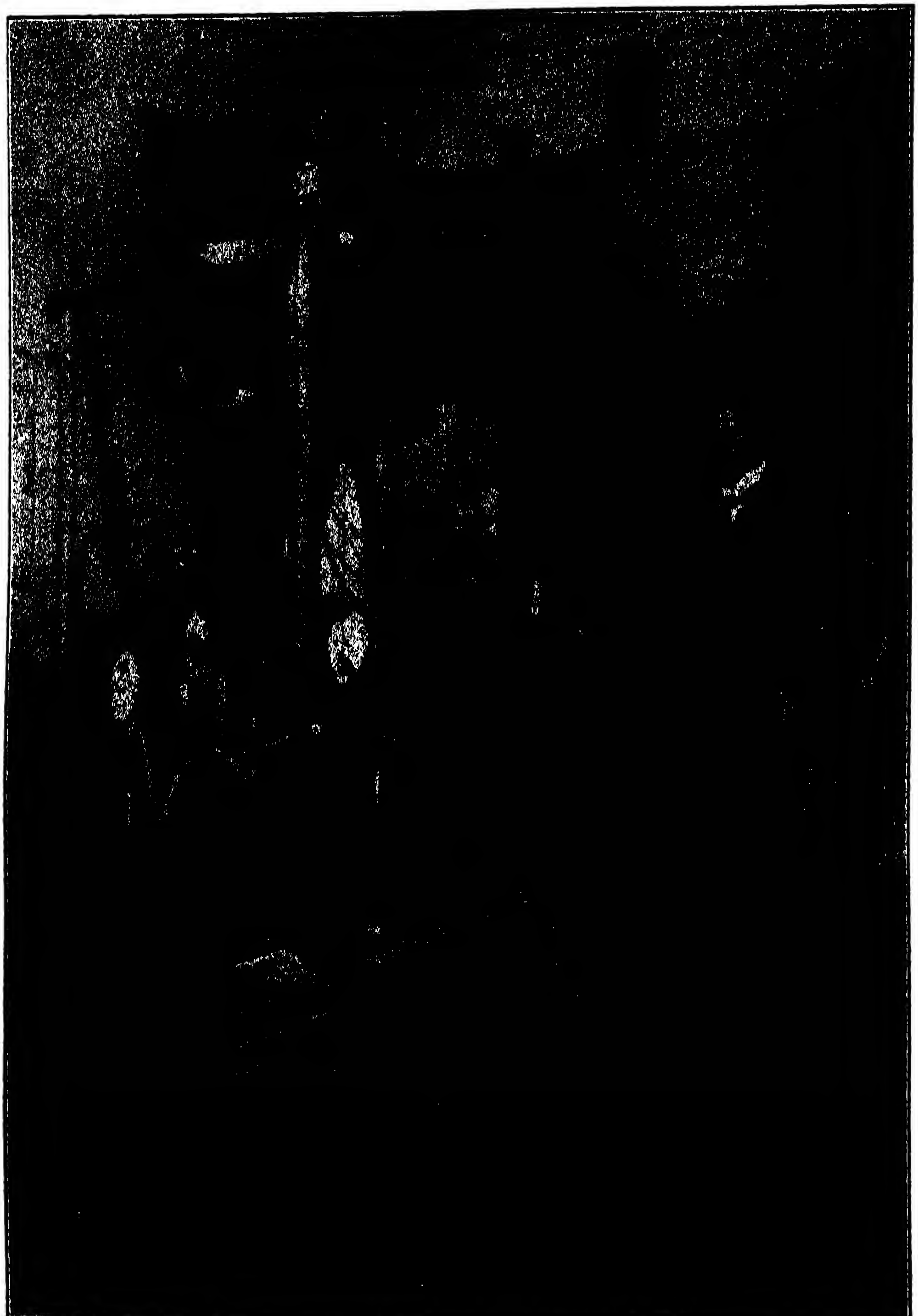
So, too, the summer girl has long been laughed at by the world at large, caricatured by the cartoonists and scolded by the moralists because she followed all too literally the advice expressed in the old song:

> Mother, may I go out to swim?
> Oh, yes, my darling daughter,
> Hang your clothes on a hickory limb
> But don't go near the water.

The portion of the sunshine that has a beneficial effect upon the physiological functions consists of those dark rays which have a wave length of less than one hundred thousandths of an inch. They increase the percentage of lime and phosphorus in the body fluids, and increase resistance to disease. Tanning is an essential part of the process. Now the "bathing beauty" (to use the conventional phrase although she is rarely bathing and even more rarely beautiful) was acting in conformity with all the requirements, so far as local law allowed, when she kept out of the water and spread herself on the sands. Unjustly accused of desiring to make herself conspicuous, she was really seeking the invisible components of the sunlight, and it is not her fault that these are inseparably associated with rays that render her visible to the passer-by and even the by-stander.

Having proved the therapeutic value of ultra-violet rays on the seashore, the summer girl has carried the bathing suit inland and now appears upon the street in all seasons in a costume that meets the requirements of heliotherapist. Though she may be barred from European cathedrals, the American maiden shelters herself under the second amendment to the Constitution, which stipulates that the right of the people to bare arms shall not be infringed. The new style of sleeves in fringes will, if they spread downward, interfere with the exercise of the right as well as the left, but so far the threatened eclipse is being kept at arm's length.

This raises a question demanding masculine consideration. Will not these



KARL MANNE GEORG SIEGBAHN

IN HIS LABORATORY OF PHYSICS AT UPSALA.

sunkist flappers when they grow up—if they ever do—be too big to beat and too smart for the unenlightened wits of men? For, as Professor Hill points out, modern masculine costume could hardly be worse from the standpoint of heliotherapy. Dr. Hill denounces tight collars and long trousers as particularly pernicious to masculine health.

Our Anglo-Saxon ancestors boasted of being "free-necked men," but their degenerate descendants are scrambling for white-collar jobs even though they involve impeding the blood supply to the brain and shutting out the sunshine from their throats.

Golf knickers are being worn oftener and longer (in time). But thick woolen stockings, though they may be more artistic and convenient, are still impenetrable to solar radiation.

The shorter the wave length the less the penetration as a rule. The long red heat rays will pass through the fingers as any one can prove by holding up his hand to the sunlight. The short ultra-violet rays at the other extreme are caught in the outer layer of the skin, yet they are, in some mysterious way yet unexplained, able to affect the entire body. It is largely these rays that cause the tanning, and also the burning and blistering when one takes the sun cure in too large a dose.

Tropical sunshine ranges no farther into the region of these shorter dark chemical rays than the sunshine of our own clime. Since the atmosphere easily absorbs the shorter rays of the sun, the best "bathing beaches" are to be found on arid mountain tops. Where complete clothing is required, either as protection against over-zealous police or excessive insolation, it may be made of a white, thin, loosely woven fabric of cotton, or some of the silk substitutes, such as rayon or lustron. This allows free passage to air and affords the least interference with the passage of the ultra-violet rays.

And if anybody objects to the lessening of clothes on the ground of morality, quote to him the saintly John Wesley: "The less clothing one wears by day and night the stronger he is."

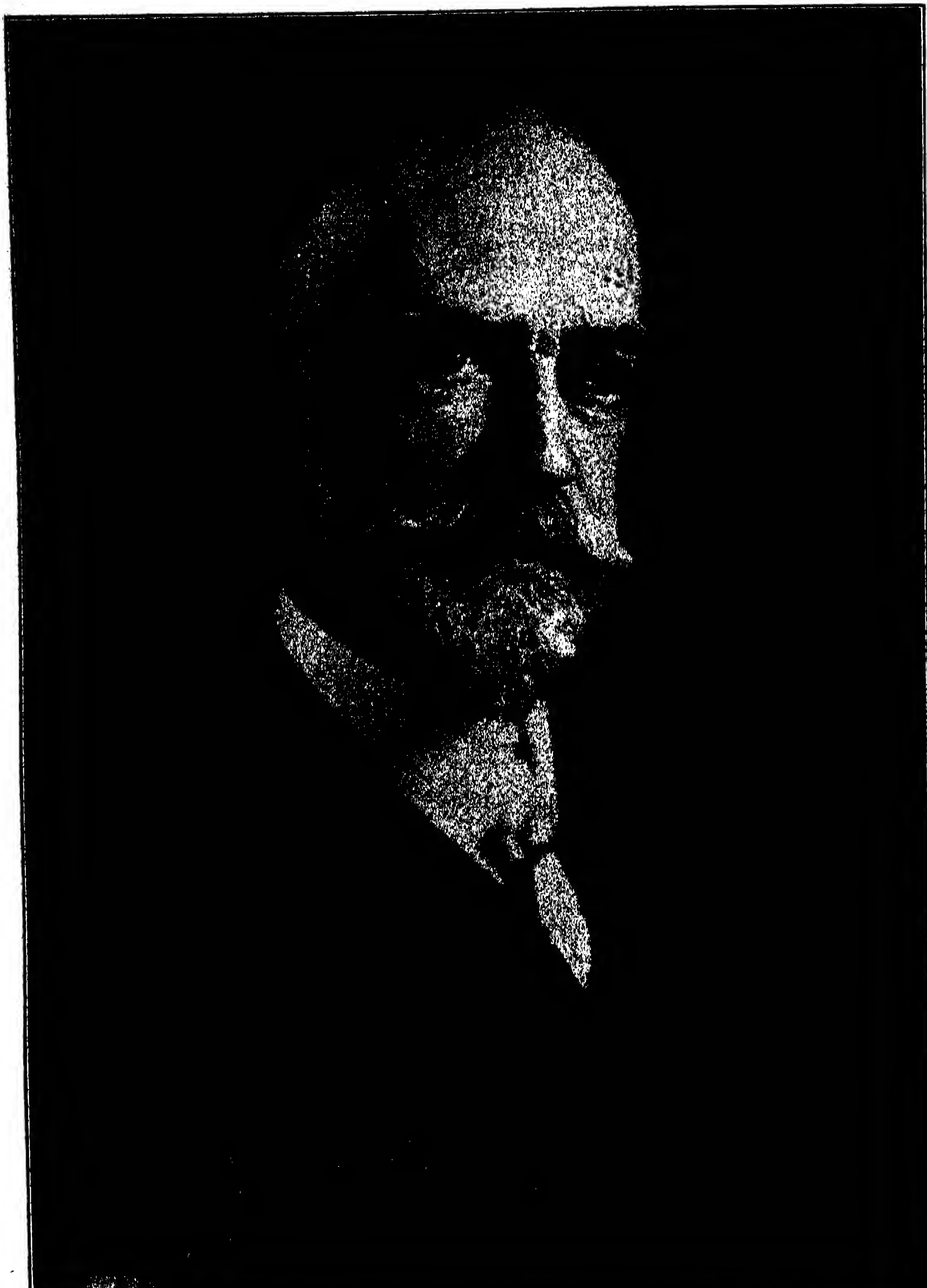
AWARD OF THE NOBEL PRIZE TO PROFESSOR SIEGBAHN

The Nobel Prize in Physics for 1924 was awarded on November 12 by the Royal Academy of Science of Stockholm to Karl Manne Georg Siegbahn, professor of physics at the University of Upsala, Sweden. This probably is the first occasion on which a man under forty years of age has had a Nobel Prize conferred upon him, although by the terms of the bequest the award was to be made for work done during the preceding year.

Professor Siegbahn has received the prize for his far-reaching work in X-ray spectroscopy. He has carried on with remarkable success the work initiated by Moseley, the young English physicist, whose brilliant career was cut short in the summer of 1915 in the trenches of Gallipoli.

The exact and arduous work of Siegbahn has made possible the measurement to six significant figures of wave lengths in the X-ray region of the spectrum. He has likewise made an exhaustive study of the soft radiations which lie between the ultra-violet and the ordinary X-ray region. His work along these lines is responsible to a large degree for the recent theoretical advances on the distribution and energy properties of the electron. These researches have led to the discovery of three new elements—hafnium and the two eka-manganeses.

The first Nobel Prize in Physics went in 1901 to the great German physicist, Wilhelm Roentgen, who discovered X-rays in 1895. The phenomena of transverse waves—be they the long waves of wireless or the almost infinitesimal



DR. WILLIAM F. DURAND

PROFESSOR OF MECHANICAL ENGINEERING IN STANFORD UNIVERSITY, DISTINGUISHED FOR HIS WORK IN HYDRODYNAMICS, THERMODYNAMICS AND AERODYNAMICS, PRESIDENT OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

"cosmic" waves just discovered by Millikan—continue to claim the attention of our leading physicists.

These Nobel prizes, each originally of the value of about $40,000, were established by the will of Alfred Nobel, who died in 1896. Nobel was born in Stockholm in 1833; he studied in St. Petersburg, and began to assist in his father's engineering works, but soon took up the study of high explosives. In 1864 he took out a patent for dynamite, obtained by incorporating nitro-glycerine with some porous substance. Later he invented ballistite, a nitro-glycerine smokeless powder, but his claim that the patent covered cordite was disallowed by the courts after a lawsuit against the British government. From the manufacture of dynamite and other explosives at his works in Ayrshire and from developing the Baku oil-fields he amassed the great fortune with which he founded the prizes that bear his name.

Three of the awards during the past two years have not been made. The Chemistry Prize of 1924 was assigned to the reserve fund of the Nobel Institute's Chemical Section. Both the physics and chemistry prizes for 1925 have been reserved. The Nobel Institute's statutes provide that if there is no occasion in any one year to award a prize as prescribed by the testator's will, the prize shall be reserved for award in the following year; if, even then, the prize can not be awarded, the prize money must be either added to capital or used to form a special fund for promoting scientific research independently of the yearly prizes. Awards of the peace and medical prizes have been withheld on five occasions, the amount of the prize money in each case being added to capital. Seventeen prizes in all have thus been funded.

THE ENGINEER AND CIVILIZATION

In his presidential address before the American Society of Mechanical Engineers, meeting in New York City from October 30 to November 4, Dr. William F. Durand, of Stanford University, reviewed the beginnings of engineering, the great antiquity of the engineering profession and its contribution to modern civilization. In concluding his address he said:

To sum up the whole matter, the engineer, either as an individual or as a collective type, is simply a link in the chain of human progress—a chain the links of which, in one form or another, run back into a past removed from our own time by tens of thousands of years, to go to no higher figures. With the trend of human progress as it now is, he seems, moreover, to be a very necessary link. He has taken upon himself the peculiar function of developing and translating into use for the needs of civilization the constructive materials of the earth and the inorganic energies of nature, and in connection with the exercise of such function he has acquired peculiar and weighty duties and responsibilities.

There are naturally the duties of self-development and improvement, both individually and collectively as organizations such as our own. This is the duty so well inculcated by the Scriptural parable of the talents. Likewise there are the duties of friendship and of cooperation for the realization of larger ends, and again, both individually and collectively as organizations.

And then it is peculiarly the duty of the engineer to see that, so far as in him may lie, these stores of Nature, of which he is the custodian, are used frugally, with due regard to their limited supply, and having in mind the needs of future

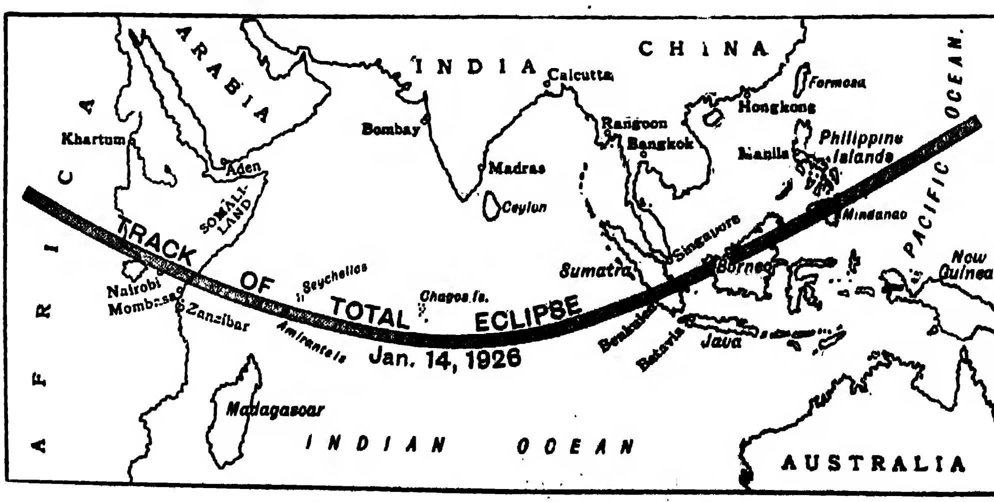
generations. Again, it is his duty to leave behind him some definite increment to that great store of knowledge through which we are able to enter into partnership with Nature, and only by means of which we may hope to more effectively align ourselves with her laws, and thus maintain an ever-ascending gradient of human progress.

Again we must individually as we may, and collectively with definite purpose, endeavor to cooperate helpfully with agencies charged with the training of recruits for our ranks, to the end that there may be a continued and adequate supply to the younger strata in our guild, whence we may hopefully look for leadership and guidance in the future.

And finally, since in the exercise of his functions as an engineer he must of necessity develop and employ habits of mind and methods of study which may be usefully employed in dealing with problems as they arise in all activities in life, therefore should the engineer stand ready to serve, not only in his chosen sphere, but wherever and whenever his habit of mind, his training and his experience may enable him to contribute a helpful element in this great cooperative enterprise which we call civilization.

THE TOTAL ECLIPSE OF JANUARY THE FOURTEENTH

Measurements of the heat of the solar corona, to be made by astronomers from Harvard University during the total eclipse of the sun visible on the 14th of next January in Sumatra and Borneo, may aid scientists in a solution of the problem of what caused the ice ages that visited the earth at times in the past. The Harvard party, the third group from American institutions to go to Sumatra, is now *en route* on the "President Harrison," which sailed from San Francisco on November 7, and will be chiefly concerned in measuring the radiation from the corona. This announcement was made by Dr. Harlow Shapley, director of the Harvard College Observatory. The expedition is in charge of Dr. Harlan True Stetson, assistant professor of astronomy, whose article on shadow bands observed at the last eclipse appeared in the December issue of the Monthly. It will also include Dr. W. W. Coblentz, physicist at the U. S.



From Nature

Map showing the track of the solar eclipse of January 14, 1926

—*Copyright by Harris & Ewing*

ASTRONOMERS OF THE U. S. NAVAL OBSERVATORY

PREPARING TO OBSERVE THE TOTAL ECLIPSE OF THE SUN ON JANUARY 14. FROM LEFT TO RIGHT, CAPTAIN F. B. LITTELL, WHO HEADS THE EXPEDITION, GEORGE L. RAYNSFORD AND G. H. PETERS. THE PARTY HAS LEFT SAN FRANCISCO FOR TEBINGTINGGI.

Bureau of Standards, inventor of the Coblentz radiometer, which was used last year to measure the heat from Mars; Mr. Weld Arnold, explorer from the Amazon expedition under Dr. Hamilton Rice, and Mr. William A. Spurr, Harvard, '25, a student in astronomy.

Similar measurements of the heat of the corona were made by Drs. Stetson and Coblentz from Middletown, Conn., during the eclipse last January. These seemed to indicate that 30 per cent. of the corona radiation is heat, and that the coronal temperature is about 5,000 degrees Fahrenheit. This is considerably cooler than the temperature of the sun itself, so it is thought to be due to the presence of dust-like particles around the sun which reflect some of the sunlight directly, causing the corona which is seen during a total eclipse, but which also absorb some of the energy, and then send it out again as long heat waves. Many such clouds of dark matter are known to exist in various parts of the sky, and it is quite likely, according to Dr. Shapley, that the ice ages in the past, during which the earth was much colder than it is now, were caused by the earth passing through such clouds, which kept out the normal supply of heat from the sun.

To collect the coronal rays, the Sumatra expedition will use apparatus ten times as powerful as that used in Connecticut, while the radiometer will be three times as delicate in measuring the heat. The largest instrument will be a 20-inch reflecting telescope. Other improvements will permit half the time consumed during the precious moments of totality to be saved, and as the eclipse will be nearly twice as long a great many more readings can be made and more accurate results obtained.

Already two expeditions from the United States have gone to Sumatra for the eclipse. These are from the U. S. Naval Observatory at Washington, and the Sproul Observatory of Swarthmore College. The former is in charge of Capt. F. B. Little, astronomer at the Naval Observatory, and also includes Dr. John M. Anderson, of the Mt. Wilson Observatory at Pasadena, Calif. The Sproul Observatory party is under the direction of Professor John A. Miller, director of the observatory, and Dr. Heber D. Curtis, director of the Allegheny Observatory at Pittsburgh, is a member of the expedition. The Swarthmore and Harvard parties will be located at Benkoelen, on the west coast of Sumatra, while the Naval Observatory astronomers plan to locate inland at Tebingtinggi.

THE SCIENTIFIC MONTHLY

FEBRUARY 1926

THE STUDY OF THE SKY IN EUROPE

By Dr. CLYDE FISHER

AMERICAN MUSEUM OF NATURAL HISTORY

(All illustrations are from photographs by the writer)

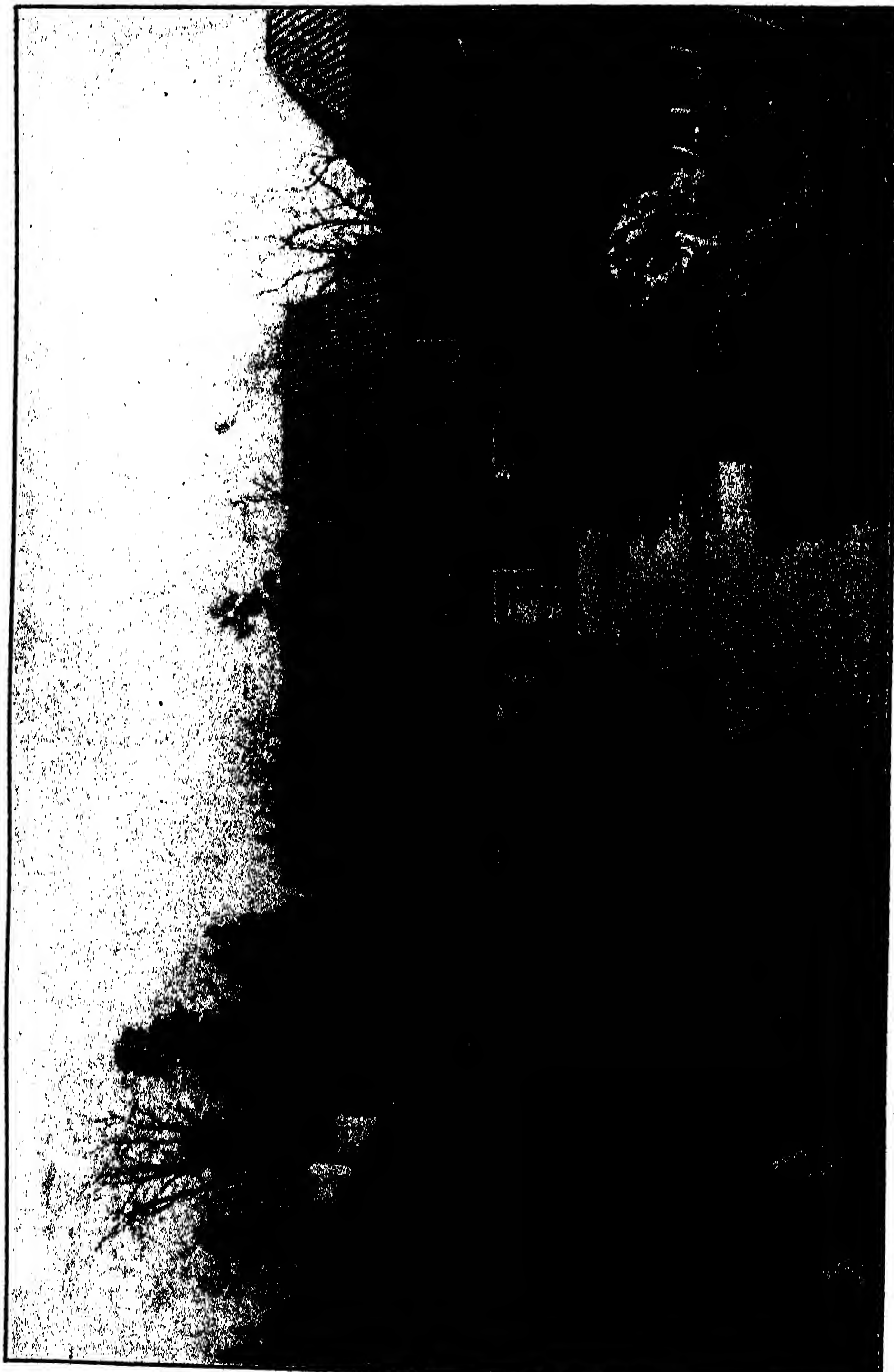
THE sun in the heavens by day and the ever-changing moon by night, the wandering planets and the scintillating stars in the night sky all engrossed the attention of man before the dawn of history, and these objects continue to absorb our interest even in this day of highly organized and complex civilization. Witness the millions of persons who turned out on an extremely cold winter day in January, 1925, to observe the awe-inspiring total eclipse of the sun! And note the innumerable amateur efforts to make photographic and other records of this rare occurrence! This is probably even more significant than the wonderful work of the professional astronomers.

In Europe more has been done and more is being done to keep alive this interest and to give it opportunity to grow than in America. In planning the proposed astronomical hall which is to be built at the American Museum of Natural History, it seemed advisable to make a survey of the methods and apparatus used in some of the countries of the old world. In pursuance of this idea, I was sent abroad in the summer of 1925 by the American Museum to make this investigation. Having the bent of an all-round naturalist, of course many things other than astronomical came in for observation. On this journey I was accompanied by my wife, whose interest and enthusiasm were as great as my own.

Going first to Sweden, I had opportunity to revisit places first seen on the American Museum expedition to Lapland in 1924, and to renew pleasant acquaintances made at that time. Here is an old civilization much more uniform and homogeneous than that of our own country. There are comparatively few persons of foreign birth or extraction in Sweden. After traveling over a good part of the country in 1924, during which time the only negroes I saw were in a variety show at the capital, I said to a Swedish gentleman, "You have no negroes in Sweden?" and he replied, "Oh, yes, we have. There are two in Stockholm and one of the mail-carriers is a mulatto."

More than ninety-nine per cent. of the people belong to the state (Lutheran) church of the country. Their schools are more highly developed than ours although not so flexible. One result of their system of schools is the remarkable fact that in all Sweden there is less than one per cent. of illiteracy.

The two complete universities, the one at Lund and the one at Upsala, were visited on my previous trip, and in 1925



HAMMARBY, THE SUMMER HOME OF LINNÆUS, NEAR UPSALA, SWEDEN. BOTH THE HOUSE AND THE GARDEN ARE KEPT AS THEY WERE IN THE EIGHTEENTH CENTURY WHEN PRESIDED OVER BY THE GREAT SWEDISH BOTANIST.

DR. AND MRS. CLYDE FISHER EXAMINING AN EDIBLE SNAIL PICKED UP AT HAMMARBY, THE SUMMER HOME OF LINNÆUS, NEAR UPSALA. EDIBLE SNAILS WERE INTRODUCED AT HAMMARBY IN THE EIGHTEENTH CENTURY BY LINNÆUS.

ASTRONOMICAL OBSERVATORY IN STOCKHOLM.

I again went to Upsala, and upon recalling the fact that the university there was founded in 1477—before Columbus discovered America—I felt that American institutions are indeed quite youthful.

At the University of Upsala, I went to see the herbarium in the department of botany. Since I had in years gone by been interested in mushrooms, puff-balls and other fungi, I wanted to see some specimens actually collected by Elias Fries, who was one of the early authorities on the subject. By the way, he is the first of three generations of the Fries family who have been professors of botany in this great university. He was followed by a son, and at the present time one of his grandsons is professor of botany in this historic institution. It was a pleasure to find specimens collected by the elder Fries in good state of preservation. I met several botanists at Upsala, among them Dr. Nils E. Svedelins, the great authority on algae.

No naturalist traveling in Sweden would fail to make a pilgrimage to Hammarby, the summer home of Linnæus, the father of modern botany, who is without doubt the most widely known botanist who has ever lived. Not only is he known to every botanist in the civilized world, but to every zoologist and to every student of the biological sciences, as well. We were conducted on this trip by Dr. E. Einar Du Rietz, associate professor of botany at Upsala. In 1924 I had climbed Mount Nuolja in Arctic Lapland with Dr. Du Rietz, and profited by his thorough knowledge of the plant life of that region.

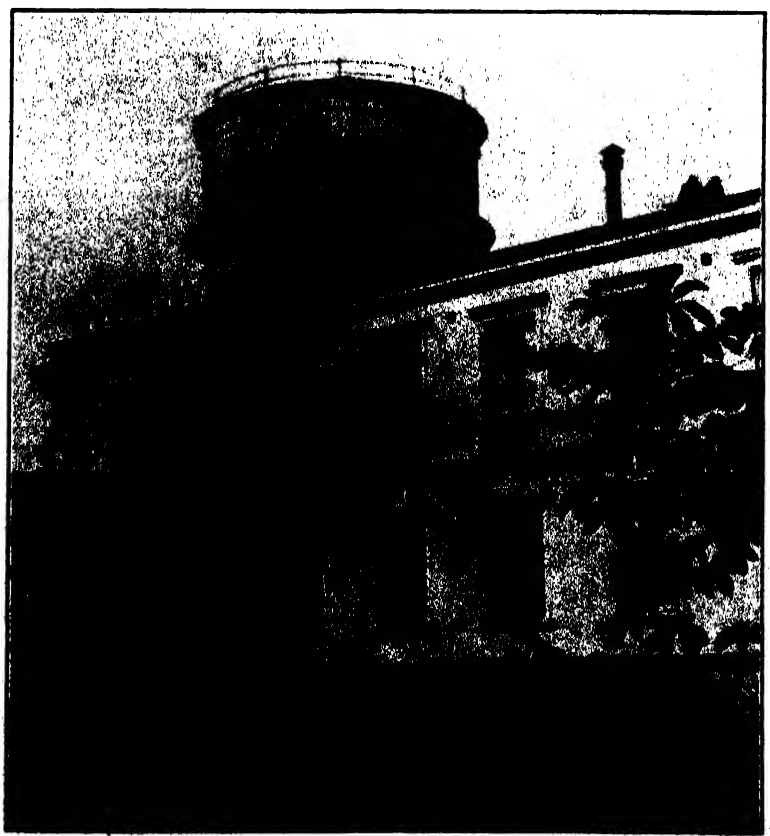
The house at Hammarby is painted red with white trimmings, as nearly all the cottages (*stugor*) are in Sweden. The garden is kept as Linnæus kept it in the eighteenth century. Back of the house is a little fire-proof museum which contains many books which belonged to Linnæus and many other things con-

nected with his life including the lecture-seat he used when professor of botany at the University of Upsala.

In the village of Upsala is the Linnæan botanical garden, kept as it was during the time of Linnæus. Near this garden is a museum of considerable size devoted to Linnæana.

By the way, the second one of the Fries line of botanists, Theodor Magnus Fries, has given us the best biography of Linnæus, and this has been used as source material for the recent Life in English by Dr. B. Daydon Jackson, secretary of the Linnæan Society of London. When in London later I called on Dr. Jackson at Burlington House in Piccadilly, and among other things examined, in the original herbarium of Linnæus, specimens of his favorite flower, *Linnæa borealis*, which he had collected in Lapland in 1732, the flower having later been named for him. I also handled and examined the original diary kept by Linnæus on his journey through Lapland. This was written in ink and was copiously illustrated with pen sketches of the Lapps and practically everything connected with their culture. It is a matter of surprise to outsiders, as it must be of chagrin to the Swedes, that these valuable Linnæana are not in his native country, but in London.

Due, no doubt, largely to the influence of Linnæus, the subject of botany is emphasized much more in the schools of



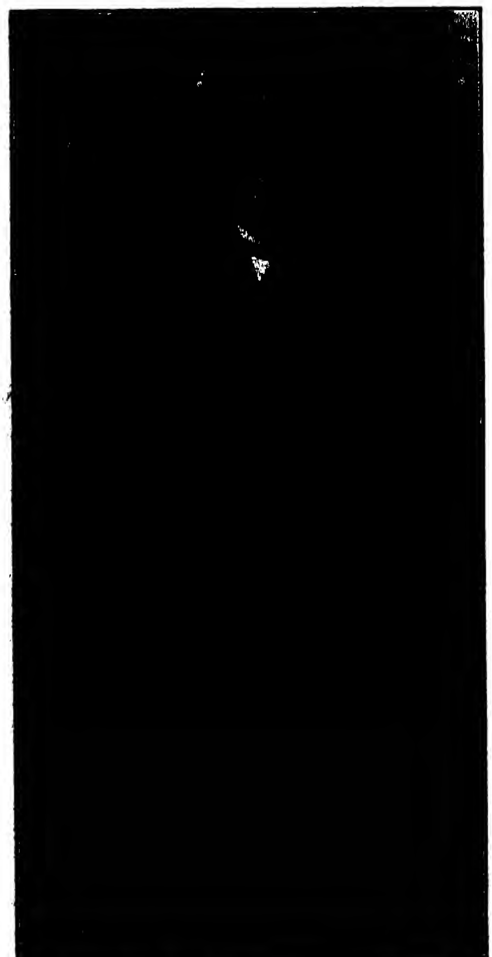
ASTRONOMICAL OBSERVATORY AT UPSALA. DR. BERTIL LINDBLAD, ASTRONOMER, IN THE FOREGROUND.

DR. EINAR LÖNNBERG, CURATOR OF VERTEBRATES, IN THE GREATEST NATURAL HISTORY MUSEUM IN SWEDEN.

Sweden than in America. It is a common sight in Sweden to see groups of boys and girls with the characteristic tin vasculums or collecting cases on botanical excursions. A large portion of their holidays and vacation is spent in collecting, mounting and identifying plants.

I found the astronomical observatory at Upsala well equipped for teaching purposes as well as for other serious work in this field. Dr. Bertil Lindblad, astronomer, who showed me their equipment, had studied at our Mt. Wilson Observatory. He recommended that I visit the uranias of central Europe, in view of our projected Astronomical Hall at the American Museum.

The State Museum of Natural History (*Riksmuséet, Naturhistoriska*) is the greatest institution of this kind in Sweden and is housed in a fine modern building. Dr. Einar-Lönnberg, curator of vertebrates, showed me through the department of mammals and birds. Quite unique is one room containing a historical collection of animals, some three



DR. NILS SVEDELIUS, PROFESSOR OF BOTANY IN THE UNIVERSITY OF UPSALA, AND WORLD-AUTHORITY ON ALGAE.

hundred in number, all having been mounted more than one hundred years ago. Some of the taxidermy is astonishingly crude, while some of it is surprisingly good. Some of the extinct animals included are a quagga, a blue-buck, a Cape buffalo of an extinct variety and a warthog of an extinct variety—all from Africa. Besides these there were several species which are on the verge of extinction.

Another hobby of Professor Lönnberg's was the most complete collection of young mammals that I have ever seen. These are mounted with adults in family groups. Baby animals are always appealing.

There is a large collection of whales and other *Cetacea* here which includes a gray whale. I believe that, with the two specimens of gray whale obtained for the American Museum by Roy Chapman Andrews, are the only complete skeletons in the world. Professor Lönnberg also has three skeletons of the extremely rare sea-otter. Professor Lönnberg has done for the birds of Sweden what Chapman has done for the birds of eastern North America. I used his handbook in Lapland.

In 1924, after my return from Lapland, I visited Skansen, the unique out-of-door museum in Stockholm, with this mammalogist and ornithologist. Here is a fine collection of living animals native to Sweden, including a part of the largest herd of European bison in the world; a pair of Swedish moose, which resemble the American species, but have smaller antlers; three hybrids between the gray wolf and the domestic dog, and the three species of seals to be found in the waters bordering on Sweden.

At the Nobel Institute we called on Professor Svante Arrhenius, the great chemist. He did not seem weighed down by his four different kinds of doctorate degrees. He is a most genial and lovable man.

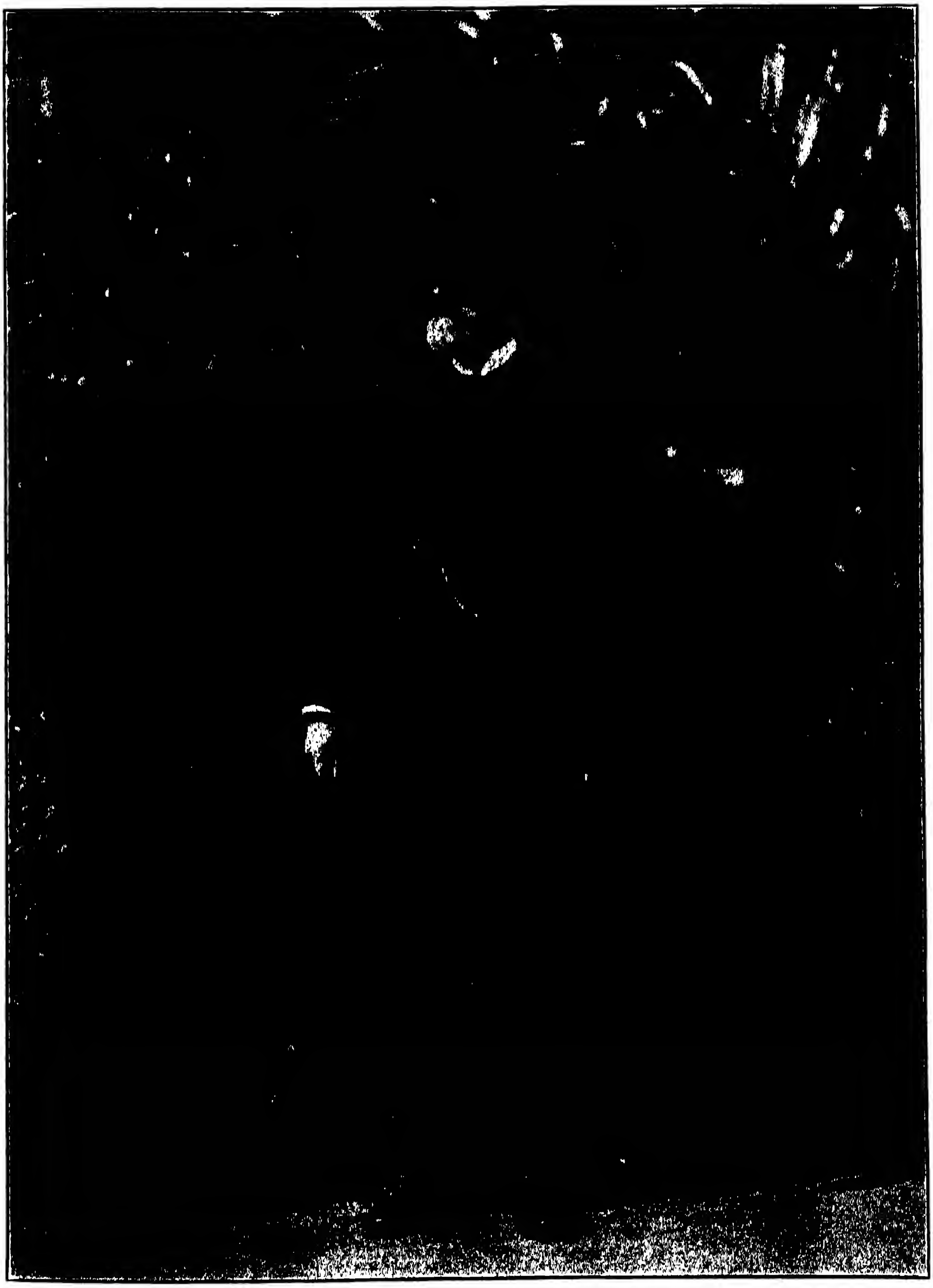
Baron and Baroness Gerard DeGeer, companion geologists, showed us their method of counting time back to the glacial epoch by means of laminated clays. This is a great contribution to science, and the results have been completed for Scandinavia, and Professor DeGeer's students are now working in Canada and other parts of North America, and have already connected up a great deal of American post-glacial time with that of Scandinavia.

Sweden is a country of great beauty, and its people are so courteous and hospitable, and so genuine with it all, that it is difficult to leave the country. But our hurried schedule made it necessary for us to make our departure, and this we did through Malmö in the south, paying a short call to Denmark on the way down to Germany.

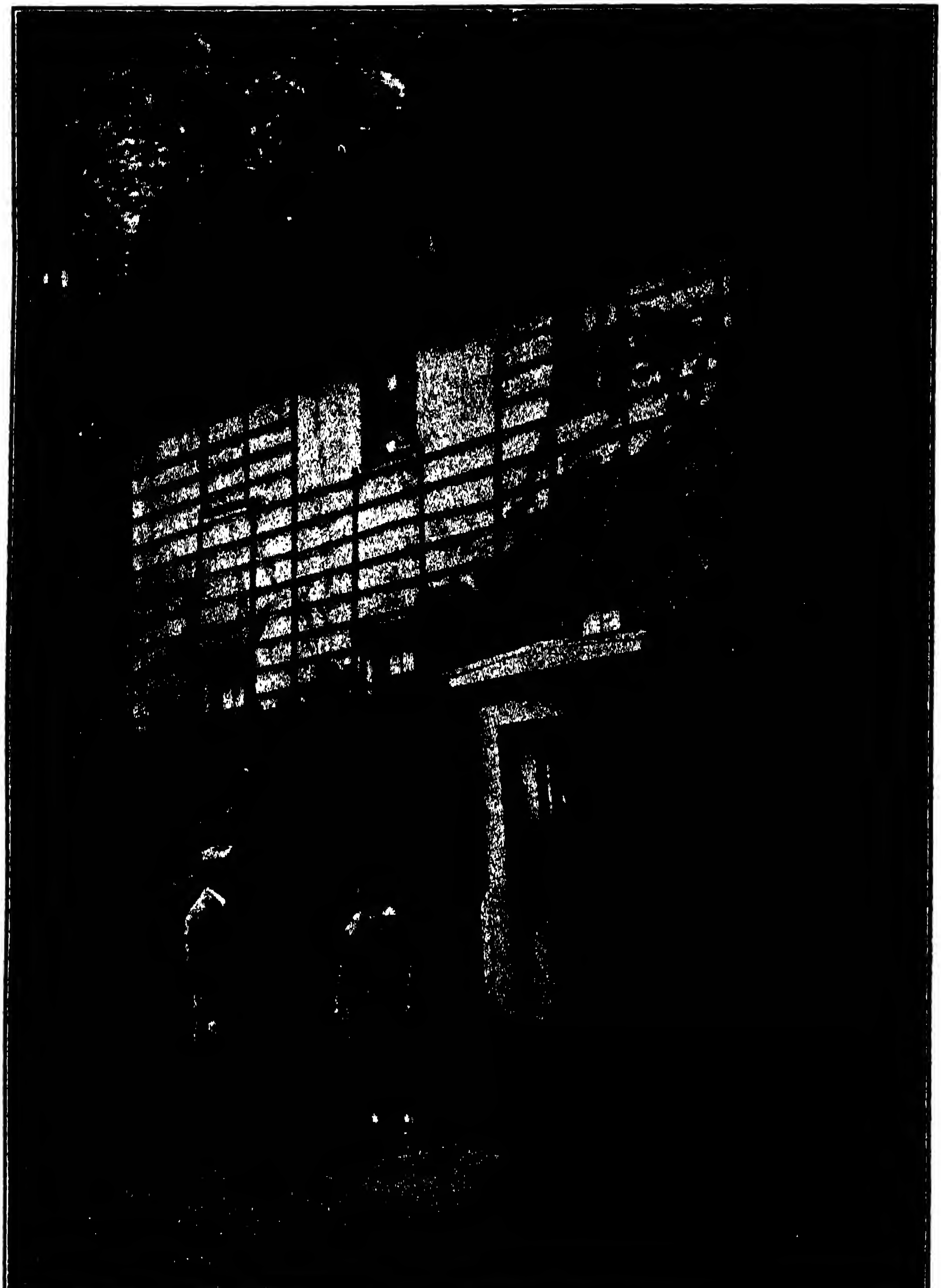
In Copenhagen we saw the astronomical observatory and learned that the director had seen the Zeiss Projection Planetarium in Munich and that he was most favorably impressed with it, a fact of significance to me because this planetarium was the principal objective point of my trip. In this city we visited Thorwaldsen's Museum of Sculpture and the Ny Carlsberg Glyptotek. I was more impressed with the beauty of the sculpture in the latter than that of any other gallery in Europe. Sinding's "Idyl" and "Natten" are particularly beautiful.

The first place we stopped in Germany was Hamburg, not for the purpose of visiting the astronomical observatory, for there is a good one in this city, but to see Carl Hagenbeck's Zoological Park (*Tierpark*) in Stellingen just outside of Hamburg. The striking thing about this "zoo" is the commodious and realistic installations of the animals. The inclosures are bounded by deep and broad and more or less hidden trenches, and one may see lions, polar bears, reindeer and other animals in their natural habi-

PROFESSOR SVANTE ARRHENIUS, FOUNDER OF THE ELECTROLYTICAL DISSOCIATION THEORY, WHICH IS THE BASIS OF MODERN ELECTRO-CHEMISTRY, PHOTOGRAPHED AT THE NOBEL INSTITUTE.



Dr. Karl E. von Goebel, director of the Botanical Garden in Munich, and Professor of Botany in the University of Munich, photographed in the Botanical Garden.



GOETHE'S "GARTENHAUS" IN WEIMAR.

tat realistically reproduced, with no bars between the animals and the observer.

From Hamburg we went to Berlin by an express train equipped with wireless telephone, the first I had ever seen on a railway train. Upon inquiry I learned that this had been installed only about two months before, and that this was the only place in Germany where the experiment was being tried.

In Berlin we saw the specimen of *Archaeopteryx,* at the Natural History Museum. This is the oldest known bird, having lived millions of years ago. It is about the size of a crow, and had teeth, which are not found in any living birds. Only two specimens of the *Archaeopteryx* are known, and both of these were found in the Solenhofen lithographic stone in Germany. One specimen is in Berlin as noted above, and the other is in the British Museum of Natural History at South Kensington, where I saw it in 1924 and again later in the fall of 1925. The Berlin specimen, however, is the better. The teeth are quite distinct, the feather impressions are more perfect and the bones are wonderfully preserved. We were surprised to find that only a cast is on exhibition in the Berlin Museum. The real specimen was shown to us by Dr. Reck, curator of geology. Since it was not on exhibition, I expected to find that the precious specimen was locked up in a fire-proof safe, but not so; it was kept in the drawer of a wooden desk used by an assistant. I am sure we should take better care of it at the American Museum of Natural History.

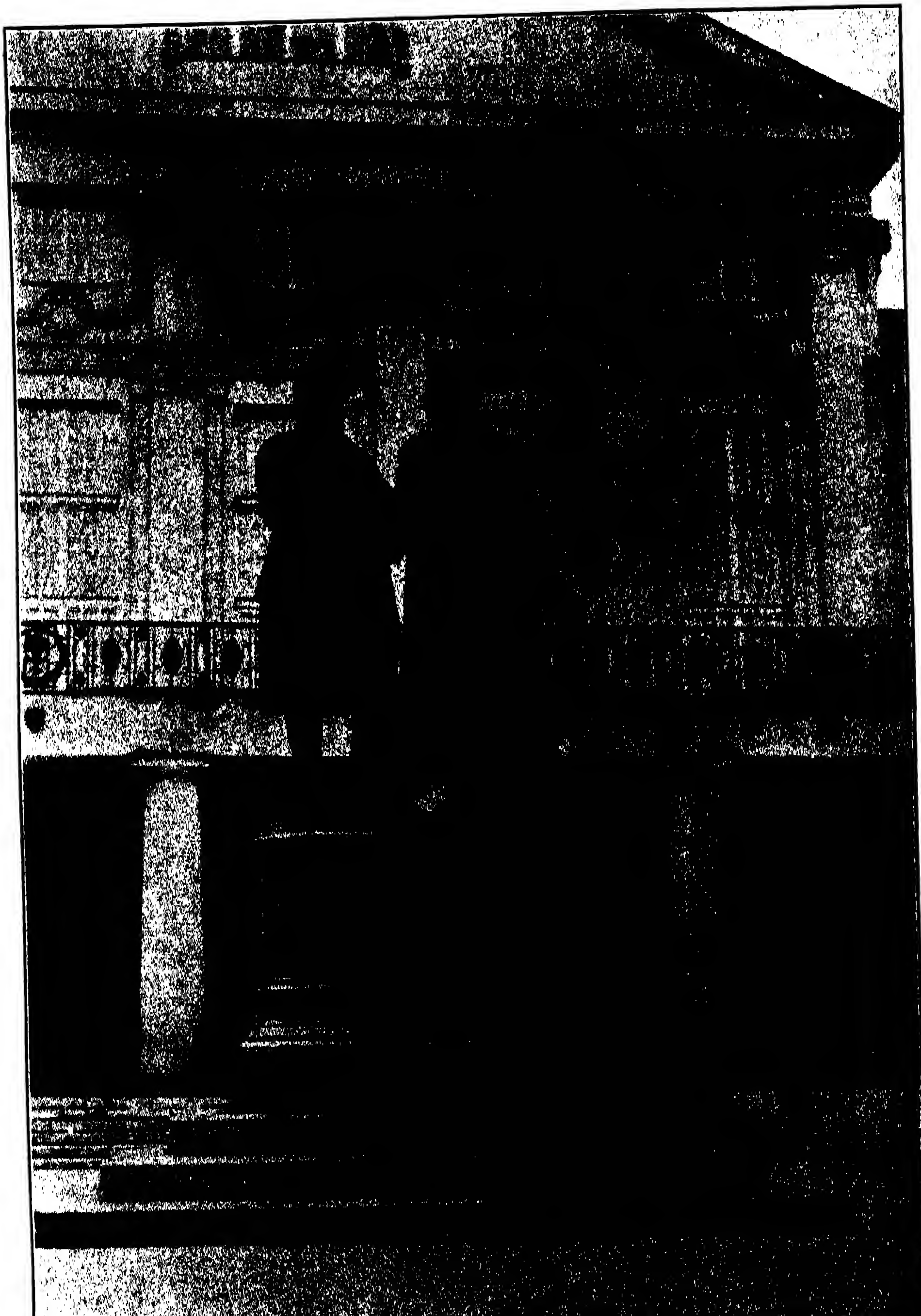
Dr. Reck also showed us some of the remarkable dinosaur remains found in Africa by the Tendaguru Expedition, for example, the only example of *Kentrurosaurus* in any museum in the world, and parts of the tremendous *Brachiosaurus,* the largest dinosaur known.

Among the habitat groups of animals was one of the beaver, which was just being made. It is to be a moonlight group, an excellent idea for an animal that is mainly nocturnal in its habits. It reminded me of a night group in the Upsala (Sweden) Biological Museum, showing a family of badgers prowling for food, and above in the trees we see how some birds spend the night, a number asleep and some awake and active, as the owl and the goatsucker. The same idea is also beautifully illustrated by the group of timber wolves on the trail in the American Museum of Natural History.

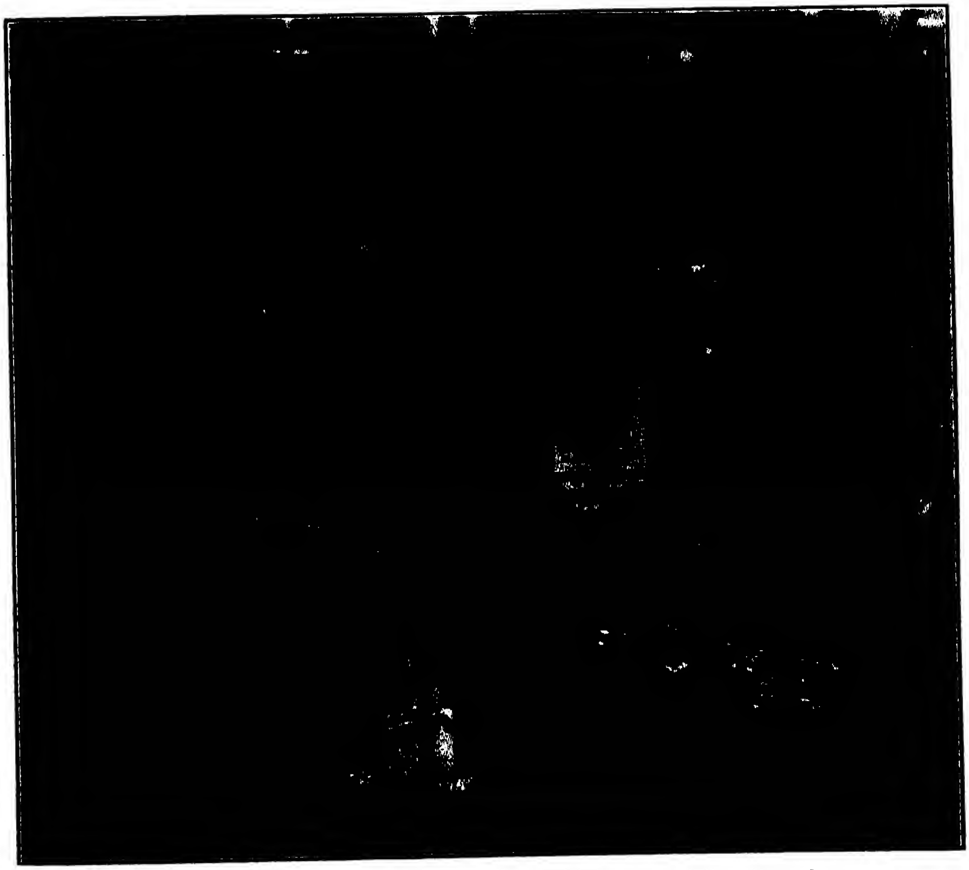
At Potsdam we visited the Royal (as it was formerly called) Astrophysical Observatory, where I examined especially their new Einstein Tower, the second one to be constructed. It is believed to be an improvement over the one at the Mount Wilson Observatory, which was the first one to be built. With this equipment the Einstein theory will be tested by measuring the displacement of the Fraunhofer lines, the spectrograph connected with this tower being very much more efficient than that connected with any refracting or reflecting telescope. The spectrum is spread out in a large room, which no one enters, and which is kept at a temperature constant to one hundredth of a degree.

In Jena we stopped at a hotel just across the street from the University of Jena, where Ernst Haeckel was professor of natural history for more than forty years. He was one of the early champions of Darwin. Schiller was also a professor here for a time.

My object in coming to Jena was to examine the newly invented projection planetarium made by the Carl Zeiss Optical Works. Several days were spent in studying this piece of apparatus, every facility having been given and every courtesy shown. Beneath a hemispherical dome, large enough to accommodate two hundred and eighty persons in this



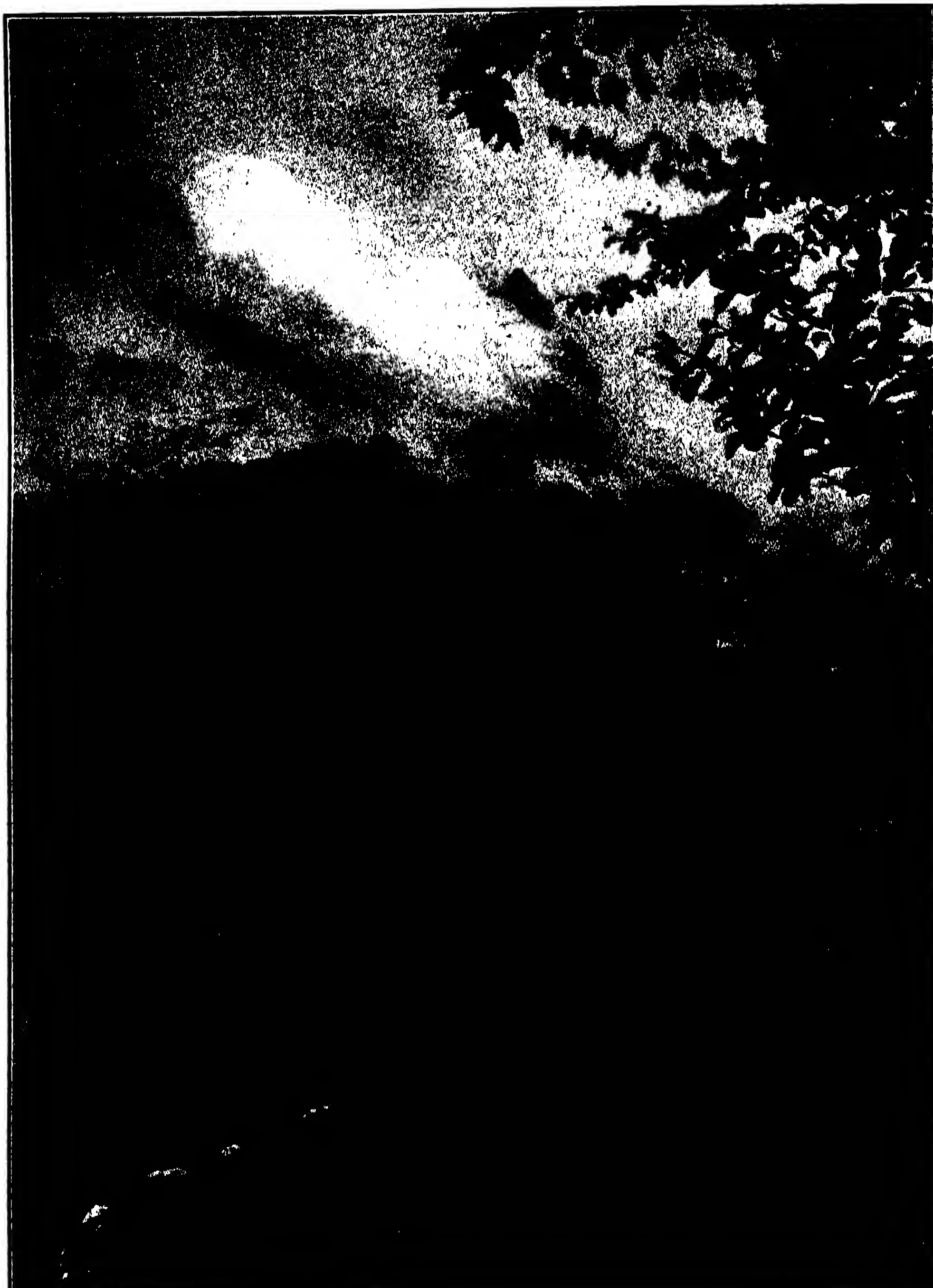
STATUES OF GOETHE AND SCHILLER IN FRONT OF THE NATIONAL THEATER IN WEIMAR. IT WAS IN THE NATIONAL THEATER THAT THE GERMAN REPUBLIC WAS FORMED.



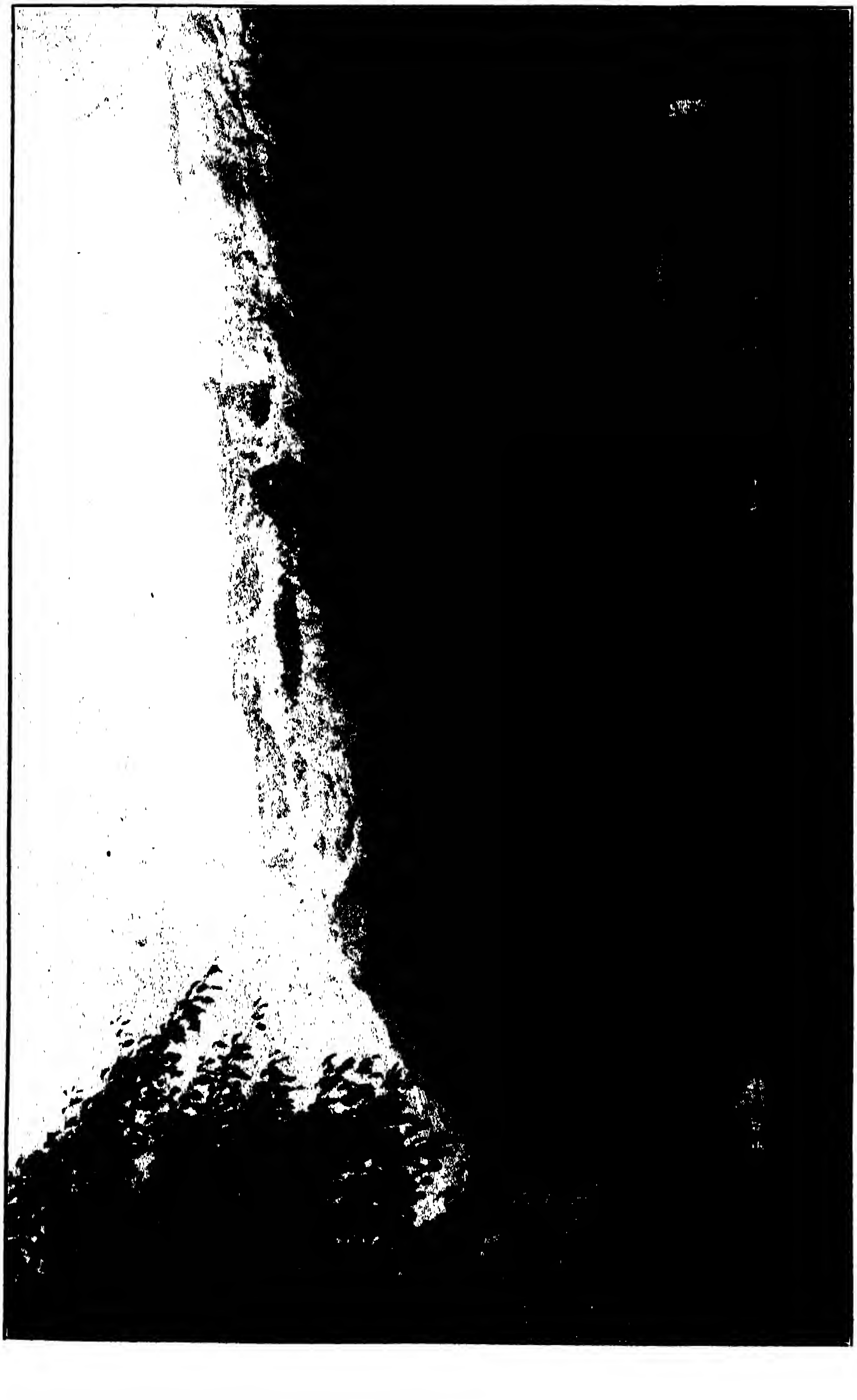
TOMBS OF BEETHOVEN AND OF SCHUBERT, IN VIENNA. ADJOINING IS A CHILDREN'S PLAY-GROUND CALLED SCHUBERT PARK. WHAT AN UNUSUAL CEMETERY! AND HOW APPROPRIATE FOR THIS COMPOSER OF SONGS!

case, is a projection machine, a kind of a glorified, animated stereopticon, by means of which is shown on the inside of the dome, the sun, the moon, all the planets visible to the naked eye, and the four thousand five hundred fixed stars that are visible to the unaided eye, including the Milky Way. These projected images move as the real bodies appear to move in the sky, with the time accelerated, due to rotation of parts of the central apparatus, which has been made and geared with such great precision that it runs with extreme accuracy. Since it is the writer's intention to prepare a special article on the planetarium, we shall not go into details here. It may be sufficient here to state that the demonstration of this apparatus had been so impressive that at the time of my visit to the Zeiss works in early September, there had already been sold eleven to German cities alone. The representation of the night sky is so realistic, the rotation of the earth on its axis is so convincing, the erratic motion of the planets is so well shown, not to mention many other phenomena which are demonstrated, that the study and appreciation of astronomy will be given great stimulus among children and laymen who have opportunity to see this planetarium in action.

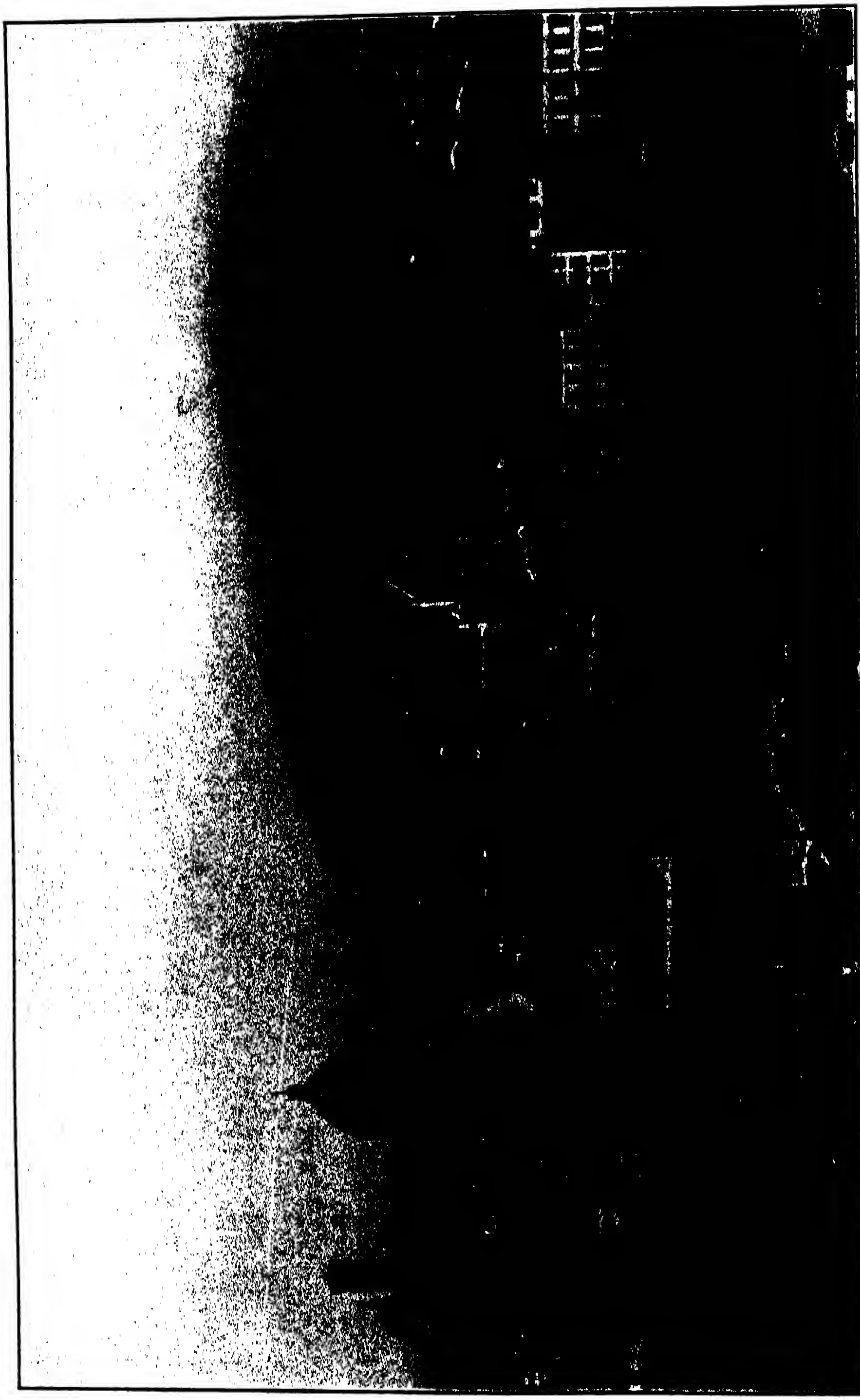
At the Zeiss Works we were also interested to go through the astronomical



MT. WETTERHORN IN THE CLOUDS FROM BRÜNIG. THE BEAUTY OF THE SCENERY IN THE ALPS SURPASSED OUR EXPECTATIONS. PHOTOGRAPHS OF THE ALPS ARE FAMILIAR TO ALL, BUT THE REALITY IS MUCH MORE IMPRESSIVE.



THE ALPS FROM INTERLAKEN. IN LATE SEPTEMBER, FRESHLY FALLEN SNOW COULD BE SEEN ON THE EVERGREEN TREES IN THE HIGHER PARTS OF THE MOUNTAINS, A BEAUTIFUL SIGHT IN THE BRIGHT SUN.



FLORENCE, FROM MICHAEL ANGELO'S PLACE, SHOWING THE CATHEDRAL AND THE CAMPANILE ON THE LEFT, AND ST. CROCE CHURCH ON THE RIGHT.

part of the plant, and to watch the building of telescopes and mountings. At another place I had my first look through an ultra-microscope by means of which I saw in a clear solution dancing particles of silver less than one millionth of a millimeter in diameter. Of course these would be absolutely invisible in an ordinary compound microscope with an oil-immersion lens of the highest power.

The Zeiss Works is a donation, as the Germans call it, to the people made by Ernst Abbe, inventor of the Abbe condenser, at that time the sole owner. He was too modest to allow his name to be used in the name of the concern, but instead used the name of the founder, Carl Zeiss. It is a cooperative organization, and all the profits go to schools and other philanthropic purposes. The scientists and technical workers are employed for life. On the staff are fifty pure scientists, not counting engineers and technical men. In the glass works, Schott, the famous expert in optical glass, although past eighty years of age, is still working every day.

From Jena we went to Weimar, thirteen kilometers distant, where Goethe lived the last fifty-six years of his life, and where also lived Schiller, Liszt, Wieland and Herder.

Goethe's Gartenhaus and his old home are preserved and open to pilgrims. Both are now shrines where many come. The old home is a veritable Goethe Museum. Here one may see his workrooms, bedroom, original library, various collections and laboratories, all kept as this great master used to keep them.

The Schillerhaus is a much more modest dwelling. Goethe inherited much wealth from his parents, while Schiller's parents were poor. Schiller's old home is now a museum, a shrine also visited by many pilgrims. Goethe's and Schiller's tombs are side by side in an old cemetery on the edge of Weimar.

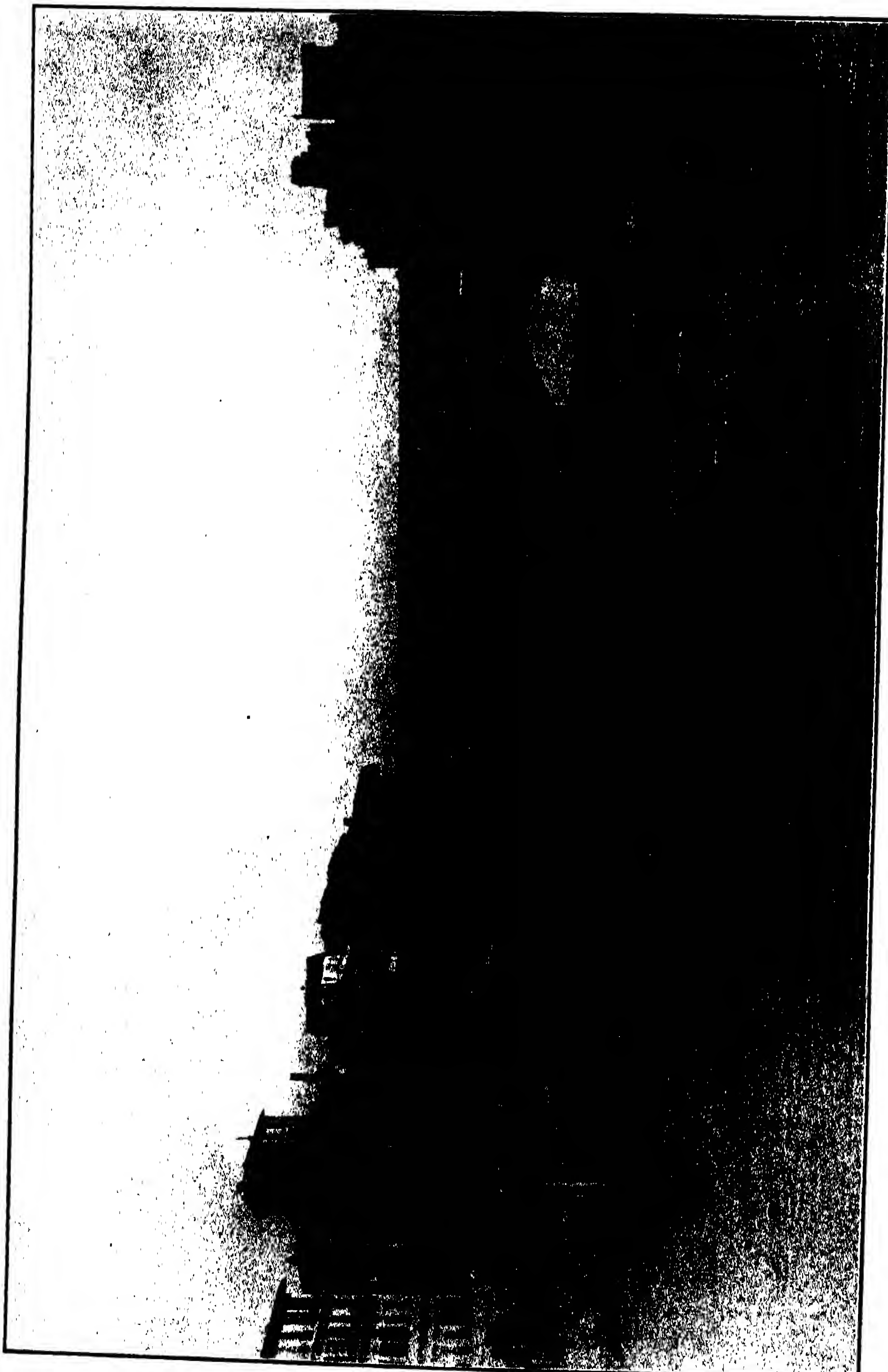
The Liszthaus is a museum kept in the same way. We were interested in the room in which he gave piano lessons, always without pay. Two or three of his pianos are in the old home, as well as a spinet upon which he got finger-practice.

On the way from Jena to Dresden, we changed trains at Leipzig in the largest railway station in Europe. In Dresden we visited the famous collection of paintings, said to be the finest north of Italy. Raphael's *Sistine Madonna* and many others attracted our attention, to say nothing of the great collection of sculpture, the Green Vault, and the collection of porcelain.

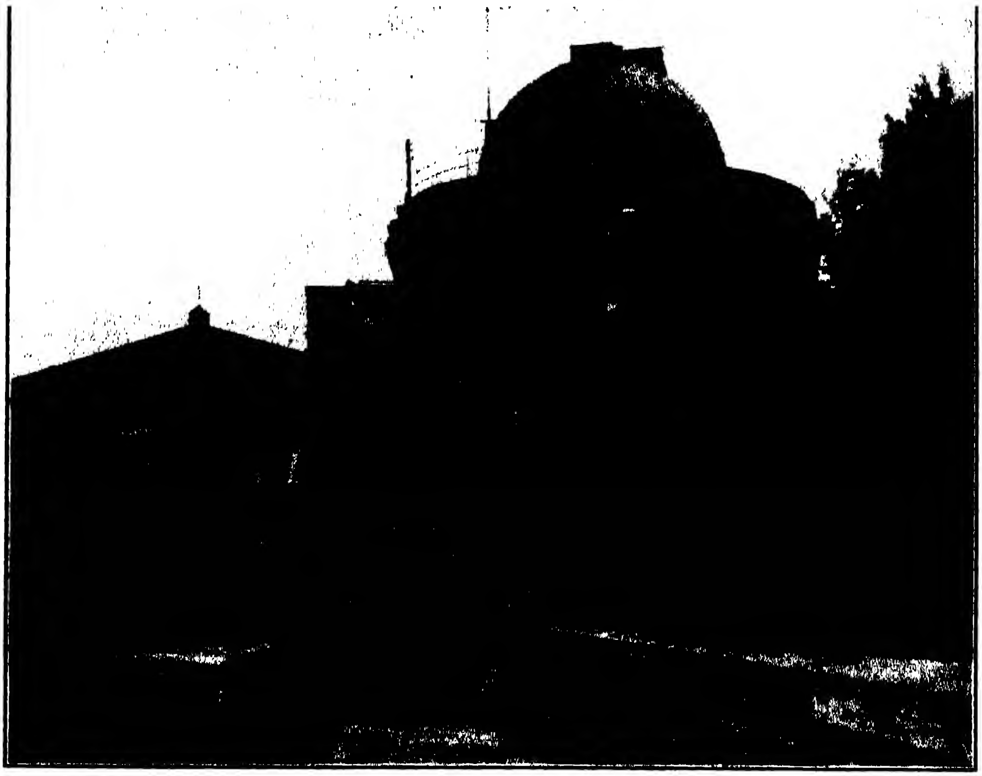
At Munich our chief interest was in the great German Museum, and in the department of astronomy of that institution. We were unfortunate in missing the president, Dr. Oskar von Miller, on account of his absence in America, but we carefully examined the astronomical exhibits, which on the whole do not have a rival anywhere. Indeed it probably would not be far from the truth to say that the astronomical exhibits of the German Museum excel all the rest of such collections in the world. More than twenty-five rooms, halls, terraces and domes are devoted to astronomy.

In one room is a large Ptolemaic planetarium in a spherical glass globe about six feet in diameter, with the principal constellations painted in their proper relative positions on the glass sphere. As it was understood in the Ptolemaic system of astronomy, the earth is stationary at the center of the apparatus, and the Sun, the Moon and the planets that were known when this theory prevailed revolve around the earth, each planet upon its epicycle. There is a crank on the outside of the sphere with which visitors may turn the whole apparatus. It is an excellent mechanism.

In another room is a Copernican planetarium of the same size, with the constellations on the glass sphere, and in accordance with this, the present-day theory of the solar system, the sun is at the center, and the eight planets with



BRIDGE (*Ponte Vecchio*) OVER THE ARNO RIVER IN FLORENCE, BUILT IN 1362. THERE ARE MANY QUAINT SHOPS ON THE BRIDGE.



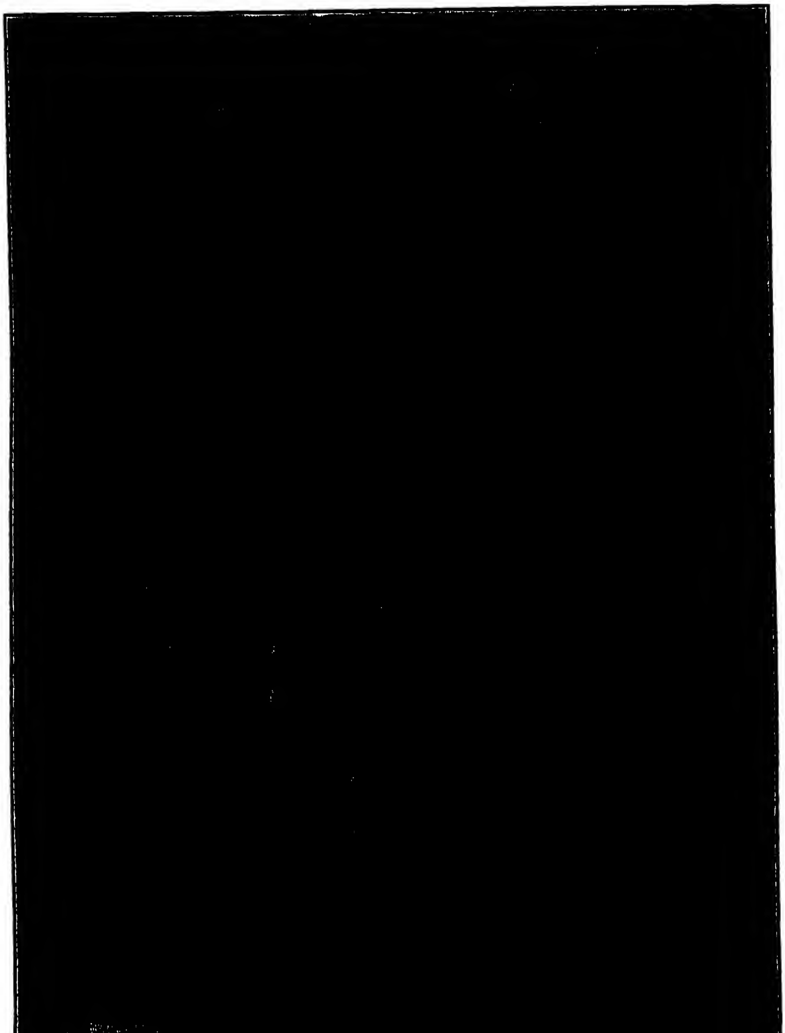
Principal Dome of the Vatican Astronomical Observatory in the Pope's Garden, Rome.

their satellites, all geared properly, revolve around the central sun. There is a crank on the outside of the glass sphere for turning the whole apparatus. This is another excellent mechanism.

The feature of a crank on the outside of these pieces of apparatus, which can be turned by the visitor, adds greatly to his interest and understanding. A similar crank was to be found attached to a device for showing the phases of the moon.

In another large room is a very large Copernican planetarium, made by Carl Zeiss. A lighted globe in the center represents the sun. The six planets nearest the sun, with their satellites—the planets and satellites all revolving at their proper relative speeds—are shown. The diameter of Saturn's orbit is about forty feet. Uranus and Neptune are left out, I presume, because their tremendous distances would make the rest so small proportionately. There is no light except from the central sun, and the walls, ceiling and floor are painted black. Consequently, day and night are well shown on any of the six planets, and so are the phases of our moon. For the lecturer or demonstrator, a car travels around under the earth, which goes around the sun in twelve minutes, the apparatus being propelled by an electric motor. The phases of Venus and Mercury can easily be observed. The constellations of the Zodiac are shown in a belt on the wall, with their names in white letters, and with the degrees of the circle marked. The stars are shown by lights back of small, round holes in the black wall.

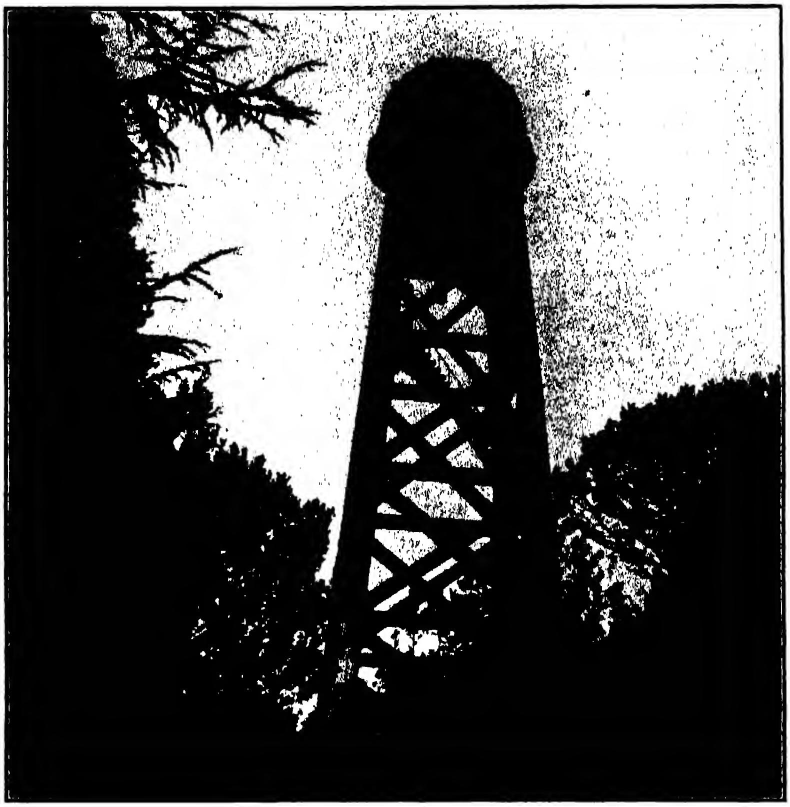
In one room, more than one hundred kinds of sun-dials were exhibited, and on an adjoining terrace the four principal types of sun-dials were set up for ac-



ORIGINAL TELESCOPES OF GALILEO IN THE MUSEUM OF PHYSICS IN FLORENCE. WITH THESE GALILEO WAS THE FIRST TO SEE THE SPOTS ON THE SUN, THE PHASES OF VENUS, THE RING OF SATURN, THE MOUNTAINS ON THE MOON AND THE SATELLITES OF JUPITER.

tual service out of doors. On clear days these attracted the attention of visitors.

The evolution of the refracting and reflecting telescopes is shown in another room, illustrated for the most part by real telescopes. Galileo's original telescope of Simon Marius, with which he saw the moons of Jupiter in 1610, the latter part of the same year in which Galileo first saw them, is here. In this room are four original astronomical instruments of Tycho Brahe.



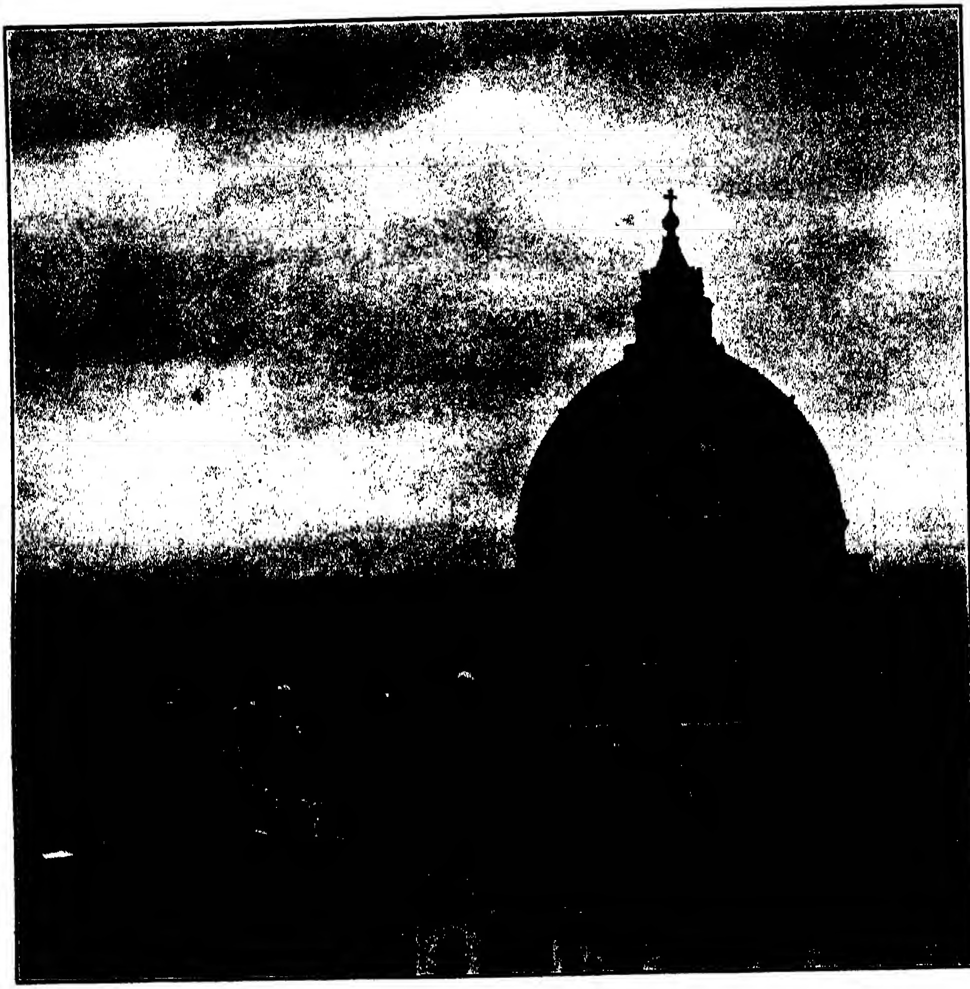
GALILEO'S TOWER NEAR FLORENCE.

tariums is installed in a dome here, and is easily the most popular piece of apparatus in the whole astronomical department. There are two lecturers who together give nine demonstrations a day. We attended one of these, at which a part of the audience was made up of a large class of pupils from a parochial school accompanied by two or three sisters.

While in Munich I called on Professor Dr. Karl E. von Goebel, the great botanist, at the botanical garden, and found with him Professor Dr. G. Haberlandt, from Berlin, who is perhaps the greatest authority on plant anatomy. It was thrilling to see these men, both of whose books I had used when a student in Johns Hopkins University.

At Vienna, in the Natural History Museum, I examined the collection of meteorites, which is said to be the finest in the world. The excellence and diversified nature of the specimens was evident.

At Vienna I also visited the Urania, which is a popular observatory in which the people may, for a small fee, observe on any clear night celestial objects through a fair-sized telescope. These observations are aided and directed by a trained person who explains what is seen. When the sky is clear enough for observation, a red light is shown on the Urania building. Usually two lectures with observations are given each evening, one rather early (eight to nine o'clock) and one rather late (ten-thirty to eleven-thirty). On the day I visited the Vienna Urania, there was a large sign at the door, stating that if the sky was clear on that night, the following objects could be satisfactorily seen: Jupiter, Uranus,



St. Peter's and part of the city of Rome, as seen from top of Dome of Vatican Astronomical Observatory

the star cluster in Perseus, and the great nebula in Andromeda. The Urania is also open during certain hours of the day for the observation of sun-spots with the astronomical telescope, and for the viewing of mountains and other distant objects with the terrestrial telescope. Later I also visited the Urania in Zürich, Switzerland.

In Rome we found an excellent observatory in the Pope's Gardens. The director, Father J. G. Hagen, is a naturalized American citizen. Taking a real interest in our proposed astronomical hall, he strongly advised the installation of a small telescope which could actually be used by visitors for viewing objects in the sky. In the Vatican Observatory we were surprised to find a little museum of astronomy, in which some of the constellations are marked on the dome ceiling of the single room. The Pole star and the stars of the Big Dipper are marked by electric lights, which when turned on illustrate very clearly how to locate the north star by means of the "pointers."

At a little *trattoria* in *Via Della Scrofa,* our waiter showed us a copy of Sinclair Lewis's "Babbitt," calling our

attention to a reference to this *trattoria,* where one can get "the best *fettuccine* in the world," a sufficient reason for going to Europe.

We spent several days in an attempt to see the Eternal City, but lack of space precludes further description.

In Florence, we visited the Astronomical Observatory and Galileo's Tower, and in the museum of physics I was greatly interested to see the two original telescopes of Galileo, with which he first saw the moons of Jupiter, the ring of Saturn, the spots on the sun and the mountains on the Moon and Venus as a waxing and waning crescent. The photograph of these telescopes was of necessity made under poor light conditions and from an unfortunate angle.

The beautiful objects of art in the Uffizi Gallery and in the Pitti Palace must at least be mentioned. The Campanile, "the most marvelous bell-tower in the world," attracted our attention, as for different reasons did the old homes of Benvenuto Cellini, Dante, Amerigo Vespucci and Galileo.

In the Paris Observatory, I found our own astronomer, George W. Ritchey, who made the one-hundred-inch disc for the big reflector at Mount Wilson. In the observatory building he is attempting to make much larger discs than ever have been made before, and on an entirely new principle. His new discs are of glass, but they are not solid. Each disc is made of many pieces in such a way that the completed disc is much lighter than the old solid disc, and it is ventilated, so that it responds more quickly and more evenly to changes in temperature.

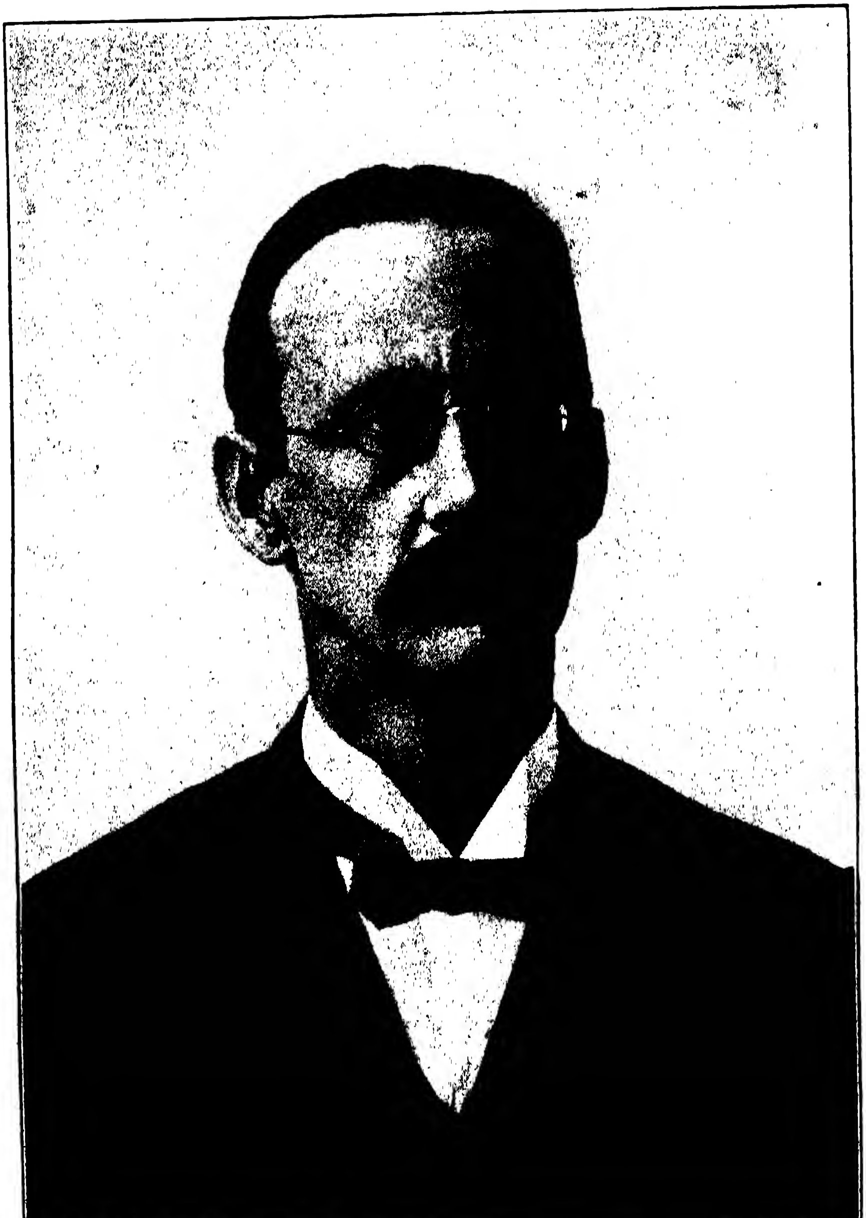
The Paris Observatory is famous for its astronomical records, especially those dating back to the early days. It is also famous for its International Time Department, which I visited, every instrument having been demonstrated for me. Here I saw permanent records being made of radio signals from Annapolis.

One could not miss the Louvre with the "Venus de Milo," the "Winged Victory" and the "Mona Lisa," and all the rest of the beautiful things there.

In the Science Museum at South Kensington, London, is an astronomical department, but not nearly so large or so interesting as that of the German Museum in Munich. However, one should mention two telescopes made and used by Sir William Herschel, as well as a number of other pieces of apparatus used by the Herschels. The first permanent photographic negative ever produced is here. It is a photograph of the forty-foot reflector at Slough and was made in 1839 by Sir John Herschel. A print from this negative is framed from rungs of the ladder of the mounting of Herschel's forty-foot reflector at Slough.

It is hoped that much valuable data for use in planning and equipping the new astronomical hall at the American Museum of Natural History has been gathered on this trip. The reasons why it is felt that one of the Zeiss projection planetariums should be a part of the equipment will be given in a subsequent article.

HILLS COVERED WITH OLIVE-TREES, NEAR FLORENCE.



ADOLPHO LUTZ

ADOLPHO LUTZ: A LEADER IN SOUTH AMERICAN MEDICINE AND BIOLOGY

By Dr. MAYNARD M. METCALF
THE JOHNS HOPKINS UNIVERSITY

Dr. Adolpho Lutz, of Brazil, has had the experience of seeing during his lifetime a complete change in the public and the medical attitude in his country toward work in public health and preventive medicine, a change from bitter and even personally menacing opposition to one of full and enthusiastic acceptance. When, as director of the Bacteriological Institute at São Paulo, he introduced into South America vaccination, isolation and regional quarantine methods against smallpox and typhoid and yellow fever epidemics he had much more opposition than support from his fellow physicians, and the people in at least one quarantined city threatened his life. The contrast in the personal feeling was shown last year at the Brazilian Congress of Hygiene which gave him a rousing ovation when he entered the hall. But the many years between had been full of strenuous and devoted work.

The great medical and biological research station at Rio de Janeiro—The Oswaldo Cruz Institute—plans to celebrate the seventieth anniversary of his birth, which occurs on December 18 of this year, and, as he is out of the country for a time on a government mission in Venezuela, his own modesty can not well prevent carrying the plans to fulfillment.

A few words of description of the accomplishments of this most outstanding Latin-American scientist may be of general interest.

Born in Rio de Janeiro of Swiss parents, he studied in Berne, London (with Lister), Vienna, Prague, Leipzig (with Leuckart) and Hamburg (with Usena in dermatology). His first scientific paper was published at the age of twenty-three, and since that time he has put out more than one hundred and seventy-five contributions. His earlier studies and publications were in the fields of dermatology and parasitology, in both of which he is still at work.

Returning from his European studies to Brazil in 1881, he took up the practice of medicine in the state of São Paulo, writing during this period several papers upon hookworm.

A few years later, when Professor Usena, of Hamburg, was unable to accept a call to go to the leper colony in the Hawaiian Islands, he recommended Dr. Lutz, who went there and was in residence at the colony for several years. Here he met the devoted English volunteer nurse among the lepers, who later became his wife. Professor Lutz has written much upon leprosy. He was the first to describe granulation in acid-fast bacilli, observing the phenomena in connection with leprosy. He believes in the carriage of leprosy by mosquitoes during those phases of the disease when the bacilli are in the blood stream. He thinks it possible that some other Diptera, but not fleas or lice, may carry the contagion. During this Hawaiian residence he wrote important papers upon rhinoscleroma and other parasitic diseases of the skin.

After his return to Brazil in 1892 appeared papers upon *Ascaries* and *Fasciola hepatica.* It was at this time that he was appointed director of the Bacteriological Institute in São Paulo and at once began his work in public

health. He was the first to identify "São Paulo fever" with typhoid. Stimulated by an epidemic of yellow fever, he met the emergency and was the first to follow in another country the prophylaxis methods so successfully used by Gorgas in Cuba in combatting this scourge, methods which since have been applied to all tropical America—thanks chiefly to the International Health Board—and which bid fair to exterminate ultimately this disease. Finding among the Paulista physicians much opposition to these then new ideas of mosquito carriage of yellow fever contagion, he with two other physicians and three laymen slept in beds and bedding which yellow fever patients had used—with, of course, negative results, and to clinch the matter in the minds of his medical colleagues, he allowed himself to be bitten by an infected mosquito, but fortunately for the state of São Paulo and all Brazil he did not contract the disease.

During this period of service as public-health officer he traveled throughout the state, inspecting conditions, especially where there was outbreak of communicable disease. It was at this time that he met the bitter opposition already mentioned, his methods being regarded as over-strenuous and his regulations as overstrict. When in the year 1900 a serious epidemic of bubonic plague broke out, he found so little help that he worked almost singlehanded, making autopsies and culturing the bacteria, as well as making the fight against the disease and its rodent carriers.

The contrast now in Brazil is most remarkable. No country is more strict in enforcing vaccination. In Rio de Janeiro and in other Brazilian cities there is inspection of all premises by a public health inspector every two or three weeks to guard against malaria and yellow fever mosquitoes and to prevent conditions favorable to typhoid fever or other diseases of bad sanitation. The effectiveness of his work, shown by the elimination of diseases formerly rampant, finally changed both medical and public sentiment, and when, after twenty years of service in the Department of Public Health, he left São Paulo to accept a call to the new research institute at Rio de Janeiro, the state of São Paulo commemorated his devoted service by a medal struck in his honor.

His São Paulo period is marked by publications, among others, upon malaria and its carriage by mosquitoes; upon malaria mosquitoes breeding in the water in *Bromilia* leaf cups in tropical forests where there are no breeding ponds or swamps; upon Haemogregarines of snakes; upon many new blood Sporozoa of birds; upon Microsporidia, many new species; and upon Trypanosome infection of cattle in the Amazon region, which was causing most serious damage.

The period of work at the Oswaldo Cruz Institute in Rio de Janeiro shows many publications, among them monographs of several families of Diptera, and, more lately, studies of Trematodes, one of these being upon *Schizostoma mansoni,* a blood fluke; and he has now nearly ready for the press a beautifully illustrated monograph upon Brazilian Batrachians, including descriptions of some thirty new species.

He has been official delegate to many international medical and scientific congresses; has received numerous medals and decorations from South American and European governments; is foreign member of many societies; is honorary president of the Brazilian Dermatological Society; was honorary president of the American Congress upon Leprosy.

This modest man, with indefatigable scientific zeal, undaunted courage and indomitable will in case of need, has seen almost the beginnings of Latin-American productive science and is now an honored and beloved leader in a group which is giving to South America a worthy place in the world of scientific research.

THE ECOLOGY IN STEPHEN HALES' "VEGETABLE STATICKS"

By HERBERT C. HANSON

DEPARTMENT OF BOTANY, UNIVERSITY OF NEBRASKA

STEPHEN HALES, according to Sachs, was "the last of the great naturalists who laid the foundations of vegetable physiology." The book, "Vegetable Staticks," was made up of papers presented before the Royal Society while Isaac Newton was president. It was endorsed by Newton and dedicated to George, Prince of Wales. The book attracted considerable attention, going through three English editions; the first in 1727, the second with amendments in 1731 and the third in 1738. A French translation by Buffon was printed in Paris in 1735, and a later revised edition by Sigaud dela Fond appeared in Paris in 1779. An Italian edition with annotations by Michel Angelo Ardinghelli was published at Naples in 1776. A German edition was published in Halle in 1748.

"Vegetable Staticks" shows the author's "genius of discovery and the sound original reasoning powers." Sachs says he was "penetrated with the spirit of Newton's age, which notwithstanding its strictly teleological and even theological conception of nature did endeavor to explain all the phenomena of life mechanically by the attraction and repulsion of material particles. Hales was not content with giving a clear idea of the phenomena of vegetation, but sought to trace them back to mechanico-physical laws as then understood." His immediate predecessors were Malpighi, Grew and Ray. Priestley was born in 1733, Ingenhousz in 1730. He occupied in respect to time an isolated position in physiology. While Hales was concerned primarily with the physiological aspects of the plant, his contributions to ecology were naïve and important.

I. ENVIRONMENTAL FACTORS

Rainfall-evaporation ratio: The annual rainfall at Teddington, England, was 22 inches and the evaporation from the soil surface 6.2 inches. Subtracting the evaporation from the rainfall left 15 inches to replenish the earth for vegetation and to supply springs and rivers. This was considered sufficient for all purposes in that flat country. In a certain hilly region the excess of the amount of rainfall over that of evaporation was still greater.

Dew: The dew was considered a very important factor. Hales reasoned that since it can not soak down into the soil to the roots before being evaporated the great benefit of it must occur in hot weather through its absorption by the above-ground parts. This would refresh the plants and furnish them with a fresh supply of moisture for transpirational losses. The beneficial effects of washing newly transplanted trees with water were thought to be due to absorption by the trees. It appears that the dew was considered valuable not only for the water imbibed but also on account of other properties contained in the dew, for he says that plants in "hot countries abound more with fine aromatick principles than the more northern plants, for they do undoubtedly imbibe more dew, . . . And if this conjecture be right,

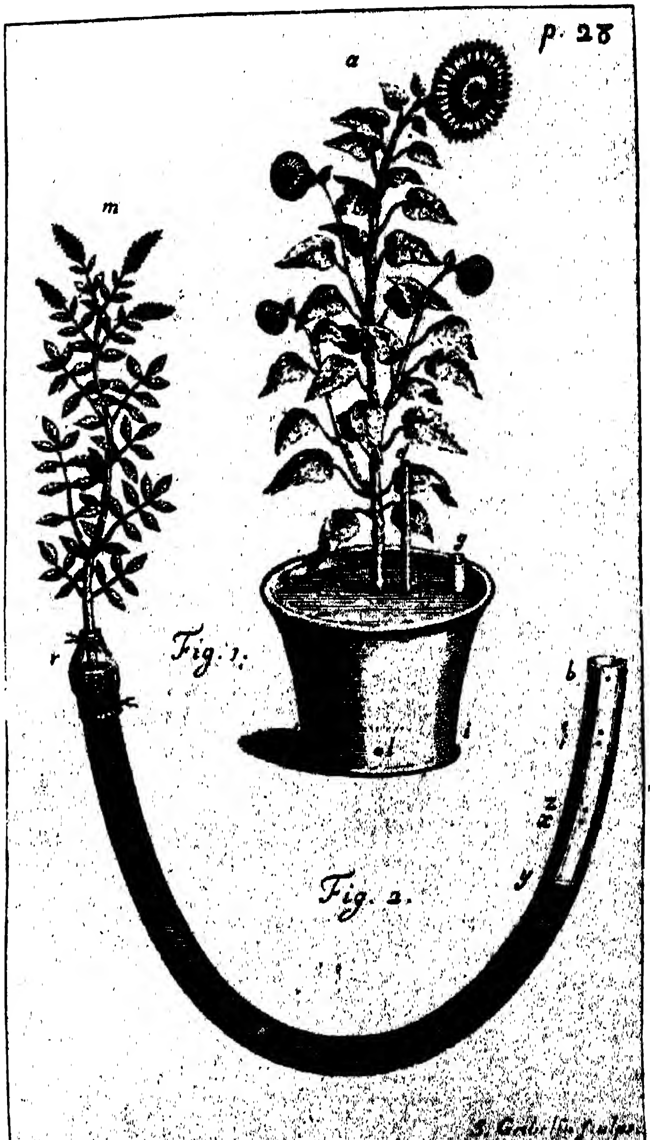


FIGURE 1. FACSIMILE, NATURAL SIZE, OF FIGURES 1 AND 2 IN HALES'S "VEGETABLE STATICKS." TWO METHODS OF MEASURING TRANSPIRATION ARE SHOWN; THE SEALED CONTAINER IN WHICH THE ENTIRE PLANT IS GROWING, AND THE CUT-SHOOT POTOMETER.

then it gives us a farther reason, why trees which abound with moisture, either from too shaded a position, or a too luxurious state, are unfruitful, *viz.*, because, being in these cases more replete with moisture, they can not imbibe so strongly from the air, as others do, that great blessing the dew of Heaven" (p. 326–327). The better colors and odors of flowers in dry soil as compared with those in wet soil were explained as being caused by the greater absorption of dew in the dry soil.

At times, however, the dew was considered harmful, for when the gardeners put bell-glasses over their cauliflowers early on frosty mornings before the dew had evaporated the dew was raised within the containers by the sun's heat and formed a scalding vapor which burnt and killed the plants.

Snow: A snow cover was considered valuable in protecting the roots of winter grain from being frozen and the shoots from fading and turning yellow in the drying winds.

Moisture content of the soil: A cubic foot of soil from the surface, another from a foot below the surface, and a third from two feet below were taken from a "good brick earth." The wet weights were secured and the soil was then air-dried. The wet weight of the surface foot was 104 pounds 4 1/3 ounces, the second foot 106 pounds 6 1/3 ounces, and the third foot 111 1/3 pounds. The losses were 6 pounds 11 ounces, 10 pounds, and 8 pounds 8 ounces, respectively. These amounts were calculated to be sufficient to supply a sunflower plant for 21 days 6 hours, after which the plant would die unless rain fell or the soil below three feet were drawn upon.

Humidity: Hales noted that some diseases were more prevalent on plants, as hops, in moist air than in dry air; that growth was more rank in moist air and more fibrous and woody in dry air; and that dry air increased transpiration while moist air decreased it.

Thermometers, soil and air temperatures: Six thermometers were made with stems varying from 1.5 to 4 feet long and with a bulb at the base. These were graduated into 90 degrees, zero being the freezing point and the maximum was evidently the boiling point of water. The optimum temperature for most plants was given as 17 to 30 degrees. The common temperature at noon in July was about 50° in the sun and 17° in the shade. In a hot-bed composed of horse manure temperatures of 75°, or more, were observed.

Readings at various times of the year were made in the air and at five depths in the soil. In August, at noon, the air temperature was 48°, in the soil at 2 inches it was 45°, at 16 inches 33°, at 24 inches 31°. In the latter part of October the air temperature was 3°, at 2 inches in the soil it was 10°, at 16 inches 14°, and at 24 inches 16°. In the first part of November it was 4° in the air and 10° at 24 inches in the soil. The thermometers placed at depths of 4 and 8 inches showed intermediate readings.

It was noted that during August the thermometers at the 16 and 24 inch depths registered about 33° and 31° until the latter part of the month, when the days became shorter and cooler. At this time they fell to 27° and 25°. Hales reasons that "so considerable a heat of the sun at two feet depth, under the earth's surface, must needs have a strong influence, in raising the moisture at that and greater depths; whereby a very great and continual wreak must always be ascending, during the warm summer season, by night as well as day; for the heat at two feet is nearly the same night and day. The impulse of the Sun-beams giving the moisture of the earth a brisk undulating motion, which watery particles, when separated and rarified by heat, do ascend in the form of vapor.

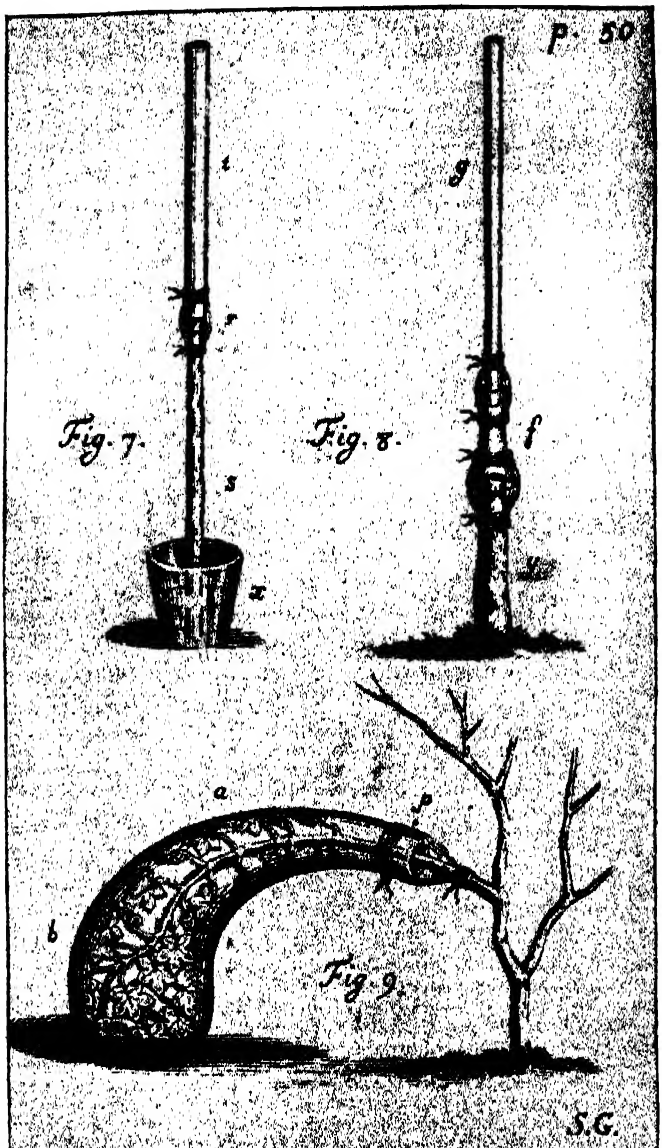


FIGURE 2. FACSIMILE, NATURAL SIZE, OF FIGURES 7, 8, AND 9 IN HALES'S "VEGETABLE STATICKS." FIGURE 9 SHOWS THE GLASS BALLOON METHOD OF MEASURING TRANSPIRATION. FIGURE 7 ILLUSTRATES AN EXPERIMENT IN WHICH HALES FOUND THAT THE WATER IN THE GLASS X WOULD PASS THROUGH THE MOIST TWIG S INTO THE CHAMBER *t*. FIGURE 8 ILLUSTRATES AN EXPERIMENT ON ROOT PRESSURE.

And the vigor of warm and confined vapour (such as is that which is 1, 2, or 3 feet deep in the earth) must be very considerable so as to penetrate the roots with some vigour" (p. 64). "If plants were not in this manner supplied with moisture, it were impossible for them to subsist, under the scorching heats, within the tropicks, where they have no rain for many months together" (p. 65).

Evergreens can endure the winter's cold better than deciduous trees, because their sap is more viscous. Snowdrops, crocus and other early spring plants are similar to the evergreens in this respect. The sap of evergreens in hot countries is not so viscous as the sap of those growing farther north. Plants on the whole are less able to endure low temperatures in the spring than they are in the fall because they contain a greater proportion of water and salt in the spring.

Wind: The tips of winter grain plants that are exposed to the drying winds above the snow cover were observed to fade and turn yellow.

Light: "And may not light also, by freely entering the expanded surfaces of leaves and flowers, contribute much to the ennobling the principles of vegetables" (p. 327).

II. Transpiration

Various ingenious devices were employed to measure transpiration. Cut-shoot potometers, branches enclosed in glass balloons to catch the moisture, as well as entire plants rooted in sealed containers were used (Figures 1 and 2). In the latter case (Figure 1) the unglazed pot in which the plant was growing was covered with thin milled lead, the joints were cemented fast so that no vapor could pass through except air through a small glass tube that projected nine inches above the lead plate. A glass tube, two inches long and one inch in diameter, corked when not in use, for watering projected through the cover. The average day loss of a 3.5-foot sunflower was one pound four ounces, the night loss varied from zero to about three ounces. A medium-sized cabbage plant in a similar container lost on an average about one pound four ounces during the day. *Musa arbor,* the plantain-tree of the West Indies, usually lost more in the six hours before noon than in the six hours after noon. The transpiration of a number of species was compared. The loss per unit area was found to be greater in deciduous plants, like the sunflower, apple and cabbage, than in evergreens like the lemon ("limon"). Twigs of elm, oak, fig, willow, ash and others, placed in potometers, raised a mercury column 1 to 2 inches; those of pear, quince, cherry, peach and plum 3 to 6 inches; but those of evergreens, pumpkins, jessamine and others did not raise the column at all. The areas of the transpiring leaf surfaces and the absorbing root surfaces were compared for several plants. The methods employed can be given best in Hales' own language:

I cut off all the leaves of this plant, and laid them in several parcels, according to their several sizes, and then measured the surface of a leaf of each parcel, by laying over it a large lattice made with threads, in which the little squares were ¼ of an inch each; by numbering of which I had the surface of the leaves in square inches, which multiplied by the number of leaves in the corresponding parcels, gave me the area of all the leaves; by which means I found the surface of the whole plant, above ground, to be equal to 5,616 square inches, or 39 square feet.

I dug up another Sun flower, nearly of the same size, which had eight main roots, reaching fifteen inches deep and sideways from the stem. It had besides a very thick bush of lateral roots, from the eight main roots, which extended every way in a Hemisphere, about nine inches from the stem and main roots.

In order to get an estimate of the length of all the roots, I took one of the main roots, with its laterals, and measured and weighed them, and then weighed the other seven roots, with their laterals, by which means I found the sum of the length of all the roots to be no less than 1,448 feet.

And supposing the periphery of these roots at a medium, to be 10/76 of an inch, then their surface will be 2286 square inches, or 15.8 square feet; that is, equal to ⅝ of the surface of the plant above ground (p. 5–7).

In a medium-sized cabbage the total leaf area was 2,736 inches, the root area 256 square inches.

In regard to the nature of the absorbing surface of the roots he states that "nature has providently taken care to cover (them) with a very fine thick strainer; that nothing shall be admitted into them but what can readily be carried off by perspiration, vegetables having no other provision for discharging their recrement" (p. 77).

The practical application of the knowledge of the ratio between absorbing and transpiring surfaces was the pruning of many branches from transplanted trees. Hales says that since about half of the roots are cut off from a young tree that has been dug up and only half of the usual "nourishment" can be absorbed it is necessary to cut off many branches. The newly transplanted trees should be well watered, but this should be done carefully so as not to give too much, causing the roots to rot and die.

By an experiment using apple twigs Hales showed that the leaves were the most important organs in causing the sap to rise. A twig bearing both leaves and fruit raised a mercury column 4 inches, a twig with leaves and no fruit raised it 3 inches, a twig with fruit but no leaves 1 inch, and a twig with neither leaves nor fruit only 0.25 inch.

The effect of various factors on transpiration was noted. Low humidity, strong light and high temperatures increased it, while high humidity, weak light and low temperatures decreased it. The transpiration of hop-vines was much greater in the shaded, moister garden than in the open. In rainy, moist weather, "without a due mixture of dry weather, too much moisture hovers about the hops, so as to hinder in a good measure the kindly perspiration of the leaves." When the trees are planted too close together he thought that transpiration was decreased to such an extent that poor fruiting resulted or that the shape of the tree became altered. In one experiment he showed that a twig inserted in a potometer raised the mercury column 11.5 inches on sunny days but only 3 inches on cloudy days.

The turning ("nutation") of the stem tip of the sunflower, facing the sun in the east in the morning and in the west at evening, was explained by the greater transpiration of the stem on the sunny side. This caused the stem to shrink on the sunny side, while the opposite side was turgid, and this produced the movement. The same phenomena were observed in the garden bean.

Transpiration occurred in winter as well as in summer. Since this loss did occur in winter, he reasoned, there must also be an ascending sap current at that season also, because the losses must be made good from the supply in roots.

One of the chief values of transpiration to the plant was conceived to be the effect on the concentration of the cell sap. When the transpiration is low "the sap is kept in too thin and crude a state," but when it is fairly high "the sap in the bearing twigs and buds is more digested and brought to better consistence" (p. 134).

III. Growth in Relation to Environmental Factors

Moisture was considered an important factor in growth. "The wetter the season, the longer and larger shoots do vegetables usually make because their soft ductile parts do then continue longer in a moist, tender state; but in a dry season the fibers sooner harden, and stop the further growth of the shoot;

and this may probably be one reason why the two or three last joynts of every shoot are usually shorter than the middle joynts; *viz.*, because they shooting out in the more advanced hot dry summer season, their fibers are soon hardened and dryed, and are withal checked in their growth by the cool autumnal nights" (pp. 333–334). The shorter and poorer condition of the hop-vines growing on the outer parts of gardens as compared with those growing in the center was explained by the greater dryness on the margins. The shade in the center helped to increase the moisture.

Light was considered an indirect factor chiefly. "Beans and many other plants, which stand where they are much shaded, being thereby kept continually moist, do grow to unusual heights, and are drawn up as they call it by the overshadowing Trees, their parts being kept long, soft, and ductile" (p. 334). The lower branches of trees in a thick stand die because since they are greatly shaded they transpire but little. The effect of reduced transpiration was considered to retard the flow of sap and to reduce the amount of nourishment contained in the sap; so evidently the branches died of starvation.

Hales noted that plants and fruits mature earlier in sandy or gravelly soils. This he thought was due to the greater warmth of these soils which was caused by their dryness. Less moisture would be absorbed by the plant, and since transpiration was high the sap would be condensed more quickly and thus hasten ripening.

Root and shoot growth were compared in early spring and summer. He noted that garden peas, beans and winter grains made poor shoot growth in winter and early spring, but the roots grew "well into the warm Earth, so as to be able to afford plenty of nourishment when the season advances, and there is greater demand of it both for nutrition and perspiration" (p. 362). But when peas are planted in June for a September crop they rarely thrive unless the summer is cool and moist, "by reason of the too great perspiration caused by the summer's heat, which drys and hardens their fibres before they are full grown" (p. 363).

IV. Disease in Relation to Environmental Factors

The influence of moisture in promoting disease was noted repeatedly by Hales. "In a rainy moist state of air, without a due mixture of dry weather, too much moisture hovers about the hops, so as to hinder in a good measure the kindly perspiration of the leaves, whereby the stagnating sap corrupts, and breeds moldy fen, which often spoils vast quantities of flourishing hop grounds" (p. 33). Large, thriving vines became heavily infected following a period of ten to fourteen days of rain, because they held the moisture within their shady thickets, while the poor and unpromising hops escaped. Apples, following a rapid growth caused by a rainy spell of ten to fourteen days, rotted "more remarkably than had ever been remembered." An observer is quoted who had noted that mold or fen was more fatal on low and sheltered grounds than on high and open ones, on north slopes than on south slopes, in the middle of fields and gardens than on the edges, and on dry and gentle soils than on moist and stiff ones.

V. Crop Production in Relation to Environmental Factors

Beans and many other plants grow to unusual heights in shaded places, and "this moist shaded state is unsually attended with sterility; very long joynts of vines are also observed to be unfruitful" (p. 334). The colors and odors of flowers were noted to be better in dry soil than in wet. The crop production

of various seasons was compared to various factors, as, temperature, rainfall and pests.

The almost uninterrupted wetness and coldness of the year 1725, very much affected the produce of the Vines the ensuing year; and we have sufficient proof from the observations that the 4 or 5 last years afford us, that the moisture or dryness of the preceding year, has a considerable influence on the productions of the Vine the following year. Thus in the year 1722, there was a dry season, from the beginning of August thro' the following autumn and winter, and the next summer there was good plenty of Grapes. The year 1723 was a remarkably dry year, and in the following year of 1724, there was an unusual plenty of Grapes. The year 1724 was moderately dry, and the following spring the Vines produced a sufficient quantity of branches, but by reason of the wetness and coldness of the year 1725 they proved abortive, and produced hardly any Grapes. This very wet year had an ill effect, not only upon its own productions, but also on those of the following year. For notwithstanding there was a kindly spring and blooming season in the year 1726, yet there were few bunches produced, except here and there in some very dry soils. This, many Gardiners foresaw early, when upon pruning of the Vines, they observed the bearing shoots to be crude and immature; which was the reason why they were not fruitful. The first crop thus failing in many places, the Vines produced a second, which had not time to come to maturity, before the cold weather came on (pp. 74–75).

VI. Root Systems in Relation to Tillage Methods

Tho' we have from these experiments, and from common observation, many proofs of the great expansive forse, with which the fibrous roots of plants shoot, yet the less resistance these tender shoots meet with, the greater progress they will certainly make in equal times. And therefore one considerable use of fallowing and trenching ground, and of mixing therewith several sorts of compost, as Chalk, Lime, Marle, Mold, etc., is not only thereby to replenish it with rich manure, but also to loosen and mellow the soil, not only that the air may the more easily penetrate to the roots, but also that the roots may the more readily make vigorous shoots. And the greater proportion the surface of the roots bears to the surface of the plants above ground, so much the greater quantity of nourishment they will afford, and consequently the plants will be the more vigorous, and better able to weather it out, against unkindly seasons, than those plants whose roots have made much shorter shoots. Herein therefore consists the great care and skill of the Husbandman, to adapt his different sorts of Husbandry to the very different soils, seasons and kinds of grain; that the several sorts of earth, from the very stiff and strong ground, to the loose light earths, may be wrought to the best temper they are capable of, for the kindly shooting and nourishing of the roots. And probably the Husbandman might get many useful hints, to direct him in adapting the several kinds of manure, and different sorts and seasons of culture to his different soils and grains. If in the several stages and growth of his Corn, he would not only make his observations, on what appears above ground, but would also frequently dig up, compare and examine the roots of plants of each sort, especially of those which grow in different soils, and were any how cultivated in a different manner from each other; this would inform them also, whether they sowed their corn too thick or too thin, by comparing the branchings and extent of each root, with the space of ground allotted it to grow in" (pp. 363–364).

DO BACTERIA HAVE DISEASE?

By Professor J. E. GREAVES

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The space upon the surface of the earth is limited, as are also the elements which are essential for the growth and normal functioning of plants and animals. Furthermore, there are certain plants and most animals which are so constituted that they must obtain their food in the form of definite compound. This requires that they receive it in a prepared form from the bodies of other plants and animals. These conditions give rise to a constant struggle for existence. It manifests itself among members of the same species; even man struggles with man for a place "in the sun." Species compete with species, the higher preying upon the lower, and so on down the line. Even the little amoeba devours the still smaller bacterium. The bacterium standing at the bottom returns the compliment, on up the line, with a vengeance, the bacteria being the greatest destroyers of all. They stand as the link between the living and the dead, acting as if they were the timekeepers in the race and fight of life. When the higher plants and animals have had their borrowed essential elements for their alloted time, the bacterium intervenes, ends the race and returns the elements to the great earthly reservoir of supply so that they can be used over and over in the never ceasing drama of life.

In this scheme of things it appears as if the bacteria stand apart from other forms of life, inasmuch as they have no smaller organisms to prey upon them. Due to their method of multiplication they never grow old; hence, barring accidents, they may be considered as immortal. It is even argued that they were the first life upon this planet, as some of them can subsist upon the inorganic constituent of the bleak rock watered with the rain, receiving their energy from the traces of nitric acid which it contains. In the course of evolution due to differentiation the higher plants and animals became mortal, thus rendering them liable to natural death and also to disease. While it is true that the single-celled forms of life never grow old and are therefore not subject to natural death, yet there are many facts which have recently been brought to light that indicate that the bacteria do not possess that enviable position of being free from the attack of smaller microorganisms.

Hankin, in 1896, found that the waters of India purify themselves. The Jumna River at Agra contained 100,000 bacteria per cubic centimeter, while three and one half miles below it contained only ninety bacteria. It is a well-known fact that these rivers are highly polluted, yet the disease-causing bacteria quickly disappear from them. This is not due to a poison, for none is to be found in them. It is probably something which is alive, for heat destroys it. While cholera organisms quickly disappeared from the natural waters, yet they actually multiplied in the same water after it had been boiled.

Hoffkin, who was in charge of a laboratory in which vaccine against the plague was produced, noted that some of his cultures of the plague bacteria would grow normally for a time, after which they would disintegrate and all the plague-producing organisms disappear. This was such a common occurrence that

the workers gave to them the name of "suicides." Why did they commit suicide? If it was a suicide what was the weapon used in self-destruction? Today we are learning that they were not suicides, but possibly still smaller organisms were preying upon them.

In 1915 D'Herelle, of the Pasteur Institute, had under observation an adult suffering with a severe case of dysentery. Each day a small amount of the feces was placed in a sterile tube of bouillon. After incubation at 37° for over night, the growth was filtered through a clay filter which removed all the dysentery bacilli. This clear filtrate was added to a second tube to which had been added previously the dysentery bacilli. This was then incubated, and at the end of twenty-four hours the bouillon was cloudy because of the great number of bacteria which had grown within it. This procedure was repeated daily for some time, when one day, upon examining the tubes prepared the day previously, there was found to be no growth. If a drop of this were carried to another tube, it was found that growth was prevented in this tube, even though it had been previously heavily seeded with the dysentery bacteria. After considerable work of this nature, D'Herelle suggested that in the filtrate was a living organism that grew as a parasite upon the bacteria and destroyed them. To this he gave the name of *bacteriophage*, meaning bacteria-eaters. Thus, fulfilling the prophetic words of the poet:

Great fleas have little fleas upon their backs to bite 'em
And little fleas have lesser fleas, and so *ad infinitum*
And the greater fleas themselves, in turn, have greater fleas to go on,
While these again have greater still, and greater still, and so on.

Having learned that there is a something which preys upon bacteria, many a question comes to the fore: How large are they? Is it possible to see the bacteriophage even with the most powerful microscope? Can they be counted? What do they feed upon? Are there different varieties? If so, do they all attack the bacteria with the same vigor? Can they be used by man to control the disease-producing organisms which attack man? These and many other questions have been asked, and some of them have been answered.

Although the bacteriophage can not be seen even with the aid of the most powerful microscope, yet they have been measured. This is done by passing them through filters the size of the pore of which has been determined. If they pass through one filter of a definite size but not through another just a size smaller, it is known that in size they must be between the two. By this means it has been found that the bacteria are many thousand times larger than the bacteriophage.

Bacteria average about one twenty-five thousandth of an inch in length; therefore, the bacteriophage are less than a thousand this size. It requires five hundred million bacteria to weigh one milligram. It would require many thousand times this number of bacteriophage to weigh this much. It is probable that bacteria are as much larger than the bacteriophage as a fly is larger than the bacteria.

These sizes approximate that of the protein molecule. It seems to leave us in a dilemma. A protein has been looked upon as the basis of life; hence, is it possible to have living organisms smaller than the protein molecule! An organism is looked upon as a cell or an aggregate of cells, and a cell as a mass of protoplasm containing a nucleus. But when we learned of the bacterium we came to define a cell as a mass of protoplasm containing nuclear material. It may be that our conception of some

minute organisms will have to be modified to read: An organism may be a micella which is composed of material more simple than the protein. Moreover, it may be, as suggested recently by Dr. C. B. Lipman, that life originated with very simple compound and not with the complex protein.

The bacteriophage can not only be measured, but they can be counted and their speed of multiplication followed. The procedure is very similar to that used in the counting of bacteria. The number of bacteria in any substance is found by diluting with a measured volume of sterile water. The well-diluted material while in the liquid state is poured into some sterile solid media. On solidifying, the bacteria become fixed on the surface and grow until they become so numerous that they may be seen with the naked eye; just as a clump of trees can be seen in the valley from the mountainside, whereas a single tree may be overlooked. Each group developed from a single organism; hence, if one knows the dilution he can calculate the number in the original sample by counting the number of such colonies.

By seeding measured volumes of the substance to be studied into heavy cultures of bacteria and then pouring onto a solid medium, the bacteriophage can be counted. The bacteria free from the bacteriophage multiply and soon become visible. But where the bacteriophage are present the bacteria are prevented from growing; hence, we have a bare space on the culture media. By counting the number of bare spots on the medium, one can ascertain the number of bacteriophage present. In this way it has been learned that some bacteriophage are found in soil, some in water and others often in the alimentary canal of man and lower animals. Furthermore, it is learned that they multiply more rapidly than do bacteria. They grow only in the body of bacteria, and when from eighteen to twenty-five have formed in the body of the bacterium it explodes; the bacteriophage are liberated and seek other bacteria on which they can prey.

Just as Pasteur found it possible to increase the destructive powers of bacteria by successive passage through the bodies of susceptible animals, likewise D'Herelle found it possible to increase the killing power of the bacteriophage for bacteria by successive cultivation in the body of bacteria. By this means many strains have been produced which quickly devour the typhoid, diphtheria, dysentery and other disease producers. Moreover, these highly active strains are found in the bodies of individuals recovering from these diseases; whereas, when the disease terminates fatally they are usually absent. Hence, they are probably often the determining factors in recovery.

Therefore, we find that bacteria have their diseases as has man. We are prone to wonder if the bacteriophage in turn have still smaller organisms which prey upon them and will science develop strains of the bacteriophage which can be liberated in water and thus free them of harmful bacteria? Will the physician of the future combat the communicable diseases of man by the use of virulent bacteriophage which will prey upon the disease-causing bacteria? Will it be possible to make immunity "catching" as is now the case with disease? The indications are that it will. Time alone will tell.

TACTUAL INTERPRETATION OF SPEECH[1]

By ROBERT H. GAULT

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ON LEAVE WITH THE NATIONAL RESEARCH COUNCIL

HERE is an experimental situation in which hands are made to do the work of ears; more accurately, a situation in which the touch organs in the palm of a hand or other skin area are performing the function of ears. This function is to receive the vibrations of the atmosphere or of a solid body that have been set up by the spoken word, for example, and to react to those vibrations in such a manner that the subject may learn to know the word or combinations of words and their meaning. This at least is the part of a total function with which I am at present concerned.

It will be apparent that in this adventure we are looking backward over the dim genetic history of our organism as it is—particularly the history of our organs of sense—to near the beginning of organic things, before highly specialized eyes and ears had grown out of the undifferentiated "mother sense of them all," as Stanley Hall described it, the sense of touch. And we are looking forward, also, to a time that may not be far away, when our friends who have lost the use of that enormously specialized organ of touch, the ear (for the ear *is* a refined mechanism for touch) may be enabled to fall back upon the very base of the sense of reality in the infinite and extended array of organs of touch in the skin. For we are here, from an unaccustomed angle, entering the gate of the great archeological field of the psychologist.

This is a suggestion of a program and in some measure a *fait accompli* in "pure" and "applied" psychology that will enlist the whole-hearted cooperation of students of physics and psychology. It is a program that is fit to stir their curiosity and to challenge their genius for experimental control.

When the skin is doing the work of ears we are confronted with a substitute reaction or a substitute reaction system. We have in recent years, especially since the World War, become thoroughly familiar with the phrase and with the fact. Feet are doing the work of hands; they are writing, sewing, handling change and manipulating tools of various sorts. One set of muscles is substituting for another that is suffering paralysis and the effect is a reaction that, to outward appearance, is healthy and adequate. The work of Franz, to name but one in this relation, is full of the meaning that, in the ordinary normal course of events in human life we have only begun to touch the edge of the possibilities of learning to adjust ourselves to our surroundings through the manipulation of our muscles, aided by a new training of sensory capacities. No one has analyzed the unusual processes of substitution that are involved in the learning to which I have alluded. It is more than probable that no one can pick out every factor that plays a rôle therein. No doubt we will all find ourselves in agreement upon the proposition that sensations of contact and of movement, which include a consciousness of position, are prominent criteria from the learner's point of view. But as aids

[1] The author acknowledges the aid that the Bell Telephone Laboratories are giving toward this research. They have provided much of the apparatus that is in use and Dr. Harvey Fletcher is generous with his assistance in relation to instrumental problems.

toward the process of substitution these sensory processes have to be brought from the background to the foreground in attentive states. This is the burden of the subject on whom the experiment is made. In course of time and experience he gets into the way of associating complexes of tactual and kinesthetic sensations that reside in the foot, for example, with the visual perception of something accomplished, whereas formerly he was in the way of making a similar association with tactual and kinesthetic sensations localized in the hand. In the last analysis the process probably comes down to the discrimination of sensory processes that have been in darkness heretofore.

Familiarity has bred indifference to many palpable evidences of the capacity of organs of touch to distinguish very small differences. Before I go on to my main problem let me rehearse a very few of these evidences.

We are familiar with the substitution of touch for vision in the case of the blind. We have begun almost to take this phenomenon for granted. The blind read by touch as rapidly as we do with our eyes; they associate tactile impressions with the meanings that others of us connect with visual impressions of the printed page; and there is no reason for assuming that any other sensory mechanism than that of touch is implicated in the performance. But not only do they employ the tactile organ in their finger tips to fit themselves into their world. After a brief period of trial and error they find their way with surprisingly little confusion amongst the buildings and trees of the campus—and without painful accident. For the touch organs in the skin of the face have taken up the burden of serving as a medium whereby the subject learns, without direct contact, of the nearness of an obstructing tree, post or pillar. Changes in the direction or pressure of air currents against the skin, alterations so slight that others of us do not observe them, become the sensory signal of such obstructions and the subject reacts accordingly. Whether this is due to an absolute increase of sensitivity or to trained attention need not concern us here. The fact is that in these circumstances behavior is altered by extraordinarily slight occasions. The accomplishments to which I have alluded afford a great amazement to the neighbors of our sightless folk who are not accustomed to thinking of the unfathomed capacity of the skin, after training, to substitute for eyes. I do not forget that in this relation the auditory apparatus comes to reinforce the tactile forces.

It has become a truism amongst students of evolutionary processes in the animal kingdom that the nervous system is an ingrowth from the skin and that highly specialized organs of sense have grown out of the primitive, undifferentiated organs of touch.

And this leads to my main purpose in this paper which is to state the hypothesis that in cases in which a specialized sense organ, notably the organ of hearing, has ceased to functionate, the organs of touch in the skin may be made to serve as a substitute. And having stated the hypothesis I shall set out direct supporting evidence for it from my own observations, and indirect evidence from the work of others.

In the first place numerous more or less casual observations serve to strengthen the hypothesis. Times without number I have noticed a group of deaf subjects whose audiometric measurement is as low as from 0 to 30 assume an attitude of attention in response to a light stamp upon the floor; a stamp that occasions a disturbance so slight that I can not believe a person of normal sensory equipment would observe it through touch alone. This is the method by which teachers of the deaf habitually attract the attention of their pupils. They feel the rhythm of the piano and

the orchestra through the floor and learn to dance to it. While they apply their fingers lightly to the frame of the piano they catch by touch the rhythmic sequence of musical tones. This is a commonplace phenomenon in schools for the deaf. But more than this, they are in many places actually distinguishing the pitch of a musical tone and reacting to it. How great a degree of accuracy the deaf can attain in this relation it is impossible for me to say. But the circumstance as it is suggests an interesting possibility to which I shall make allusion later. As a matter of course observations of this sort have not always been made under experimental conditions, and some discount upon them may be necessary. But after all our discountings, and after we have made all our allowances for the enthusiasms and prejudices of casual observers, a residue of inescapable fact undoubtedly remains: a residue of fact that at least adds respectability to the tentative conclusion that our organs of touch are devices for adjustment of so delicate quality that, if properly trained, they could catch the musical phrases of the human voice and differentiate them with a clearness sufficient to enable the subject to associate meanings therewith. To this end we will assume, as a matter of course, that it will be necessary to adopt some mechanical contrivance to amplify the vast succession of stimulations and to bring them to bear upon a pattern of tactual organs with best effect.

Experimentally controlled observations upon the capacity of organs of touch to differentiate the vibrations that correspond to human speech are available.

Two years ago one of my own students, a hearing subject whose auditory organs were completely isolated from stimulation, distinguished thirty-four words uncombined in sentence form. When selected words from the list were combined to form sentences, he grasped their meaning; and numbers of combinations were so employed. No more complicated mechanical aid was brought into requisition in this instance than a metallic speaking tube one end of which was closely covered by the learner's palm while close against a funnel at the opposite end was the mouth of the speaker. It is beyond one's power to conceive of the infinite patterns of stimulating pushes of air from the speaker's mouth through the tube against the subject's palm that made all these discriminations possible. But in time the discriminations were made and with a high degree of accuracy. Not only so, but thereby something new was built into the subject's personality; how permanently I can not say, but after the summer vacation following—a period of no practice—when he returned to us he had dropped but thirteen points on his learning curve from 92 to 79. This is a forgetting rate for tactile stimuli, under our conditions, of but a trifle more than 14 per cent. The whole observation speaks eloquently enough of a forgotten angle of the energies of men. May it not be that cycles of time in which the great upward evolutionary push of life, building form after form of more and more complicated organic devices for adjustment, have covered up primitive functions at the foundations of the structure; functions that have become vestigial and that can be led to resume their usefulness when there is need? Here may be a discovery, or a rediscovery, of a substitute for a highly specialized organ of sense.

And so the stage has been set by these observations for a more refined method and for more intensive application. The speaking tube has been discarded. In its place we have a telephonic sort of device. What would be the ear-piece in a telephone system or in an acousticon is held in the hand of the learner, so that he *feels* the words of the speaker at the other end of the system quite as you and

I hear what our neighbor is saying to us from beyond the central exchange. We thus obtain a sharper tactual impression and probably a wider range of tactual patterns than we obtained in the speaking-tube situation. The theory is that no two sentences and no two words feel precisely alike. There may be the minutest difference in many instances; so slight that to the untutored they are non-existent, but yet distinct enough to emerge into the consciousness of the highly trained. And I have personally become aware of this emergence in the case of the words: "a," "e," "i," "o" and "u" so that I could identify them ninety-one times in a hundred. They do not feel alike. One is rough and another smooth; they are long and short; one has two camel back humps upon it. They taper from indistinctness to distinctness and the reverse. There must be an infinitude of shades of difference when the touch characters that correspond to these spoken words are combined with vocalized consonants and with surds. Obviously it would be a work of Hercules, but by no means an impossibility, to make a tactile survey of such combinations as these to correspond to an auditory survey such as has been made by aid of a high quality telephone. It has been begun and it will ultimately be finished. Even with relatively crude devices on the order of the telephone my deaf-mute subjects have learned with a high degree of accuracy to identify any one of twenty sentences of six monosyllabic words each, a large number of words uncombined in sentence form and certain vowel values pronounced in isolation. They pick up a simple story by touch and show encouraging indications of a growing capacity to combine the feels of words into hitherto strange sentences, even though several unpracticed words may be thrown into the gaps. That is to say, they are commencing to do by touch what hearing people are doing by hearing all the day. For how many of the separate words uttered from across your dinner table do you really hear? Many of them you fail to hear as words at all. But you fill in the gaps; you get the sense of it all and you enjoy companionship with your dinner guests. Not the least encouraging feature in connection with this experiment in interpretation of speech by touch is the fact that the progress I have referred to has been made in but one daily practice period of only twenty-five minutes, five days weekly from the middle of October, 1924. School vacations and examination periods and days of absence for sickness, etc., have come out of these weeks. When all deductions have been made each subject is found to have practiced only about fifty-five hours to the end of the academic year 1924–1925. And furthermore it must be borne in mind that the deaf-mute subjects can hardly be expected to be burning with zeal for the experimental work. They can communicate with each other so easily by manual signs and they are by no means of the sort of well-trained laboratory students. On the other hand they approximate much more closely to the average freshman in college.

The fundamental facts in relation to the hypothesis I stated a while back have been demonstrated directly in experimental conditions. It is possible to understand speech by the agency of touch alone. How wide may be the scope of capacity for understanding in this manner? Experiment and experiment alone can afford a satisfactory answer.

Certain indirect evidence is at hand in support of the hypothesis that lies at the basis of this discussion. This evidence serves the double purpose of throwing light upon the usefulness of our hypothesis and of pointing out the direction that further researches must take if they are to furnish an answer to my question as to the *range* of our capacity to understand speech by touch.

In the first place how sensitive is the skin to tactual impressions? It is a mat-

ter of common observation that sensitivity varies with the area that is stimulated. On the forehead and temples a pressure of two thousandths of a gram will occasion a sensation of touch; two thousandths will serve upon the finger tips likewise. A much heavier pressure is required for this purpose upon the back of the neck. On the palm of the hand four thousandths of a gram has been determined to be the minimal stimulus; and the same figure, approximately, describes the sensitivity of the skin of the abdomen. But such determinations as these are made for but a single contact and upon subjects who have not been specially trained over a prolonged period. It is impossible to say with any approach to exactness what the figure should be, assuming a very rapid succession of minimal stimuli upon a given narrowly circumscribed area. Certainly our casual observation suggests that in such circumstances a stimulation by considerably less than the figures quoted above should occasion a sensation of touch. For there is such a thing as a summation of stimuli—or better perhaps in this case—an increasing excitability of a sense organ. Witness the experience of a squirrel hunter. After several months of no practice he distinguishes inexpertly at best the body of a squirrel from the bark of a tree. But after a day or so in the woods he makes the distinction unerringly. It is as if the sense organ had become keyed up by use. A drop of water falling through a short distance upon the face occasions a very slight and a pleasant sensory disturbance. Let it be repeated periodically and with very short intervals for a few minutes and the same intensity of stimulus awakens a succession of sensory experiences that are not only distinct but may be even painful.

But because we are interested in the possibility of transmitting the ordinary vocal vibrations characteristic of speech to the skin and in making them impinge thereon in such manner as to enable the subject to understand what is being spoken, we are concerned with more than the absolute sensitivity of the skin. We want to know its *relative sensitivity;* relative, that is, to the sensitivity of the ear. Assuming that we have the fractional gram weight that is essential to arouse a sensation of touch is it comparable with the shock of air impulse measured in fractional grams that is required to awaken an auditory sensation? If there is no considerable coincidence of stimulus ranges in these two sensory areas, and no possibility of developing such a coincidence, further pursuit of our experimental inquiry is already doomed to futility. But there is no occasion for entertaining a fear upon this point.

We are indebted to Dr. Fletcher, of the American Telephone and Telegraph laboratories, for searching investigations relating to the sensitivity of the ear. Speaking only of the hearing of pure tones these investigations show that variations of air pressure upon the auditory mechanism ranging from one one thousandth to one one hundredth of a gram will arouse sensations of tones whose frequencies range from approximately 200 to 16,000 per second. This is assuming a suitable energy of vibration. When the pressure upon the auditory organ is increased to one tenth of a gram we have a situation that is adequate to occasion sensations of tones whose frequencies range from 64 to approximately 16,400 per second. Recall now the fact that single contacts involving pressures of two and four thousandths of a gram, respectively, upon the forehead and palm are adequate to arouse a sensation of touch. If two thousandths of a gram weight were descriptive of the very slightest stimulus that in the most favorable circumstances could occasion a sensation of touch we should be able to obtain through the skin an impression that corresponds to tones whose frequencies range from 512 to more than 8,000 per second, provided that the sensory mechanism would permit of discrete sensations, without

fusion, in the higher range. But I am confident that a normally sensitive subject, after considerable practice, may distinguish pressures of very much less degree than is indicated by the figures I have quoted. At the same time I am not able at the present moment to submit experimental data in proof.

Assuming that what has been presented to this point is a conservative statement of the facts, it is evident that the relative sensitivity of the skin and the ear presents no insuperable obstacle to the ultimate understanding of speech by touch; and this may be said even if it were not possible to lower the threshold for touch beyond the limen that I have mentioned for the forehead, finger tips and palm.

In this connection it must be remembered, too, that suitable devices enable us to amplify vocal vibrations and thus to compensate for the insensitivity of the skin relative to that of the ear.

Another problem is before us: assume, if you please, that the threshold for touch is capable of reduction to whatever level may be desired. If, however, variations in pressure against the skin should fuse when they succeed one another at the rate of 128 to 256 times per second and above so that a fork, for example, vibrating at such a rate against the skin should seem to be not in motion but quite at rest we should at once probably find ourselves lacking an essential criterion for distinguishing speech. But fusion does not occur at any such low level. When it does come to pass in a highly practiced subject is impossible to say at this moment with anything approaching exactness. Dr. Herrick states that it does not occur below 1,552 complete vibrations a second and von Wittlich, more conservatively, places it at 1,000. If this is a fact it is of extraordinary importance for this investigation, for the reason that the frequencies employed in ordinary conversation are probably for the most part below 1,000. The point of fusion is capable of experimental determination and it must be pressed to a conclusion. Suffice it to say that instructors of the deaf regard it as no accomplishment worthy of more than a remark when their pupils, after three or four exercises, with fingers resting lightly upon a piano frame, distinguish the C of 256 vibrations from the C of 512 vibrations, and from a rate midway between the two. But the niceness of discrimination between the two extremes is, of course, a problem in itself, distinct from that of the limits. This, too, is open to experimental examination, and it must be pushed to an issue.

In conclusion, we are entitled at the present stage to a very high degree of confidence that a mechanism may be developed and a method whereby deafened pupils in their seats at school may be made to understand by touch what the instructor is saying to them. There are other possibilities; touch may be made an aid in teaching and in learning to read the lips; and it can now be asserted as a fact that deafened folk who have lost or are losing control of their voices may reestablish control by aid of a suitable medium between the vocal organs of a speaker and the skin of the subject. When the vocal vibrations from a speaker's mouth are translated into sensations of touch upon the skin of the deaf-mute he has a set of cues whereby he is able the better to control rhythm, phrasing, pitch, enunciation, accent and emphasis. When these things shall have been accomplished there may next be found a way whereby our deafened friends may know what we are saying to them in social intercourse because they can feel our words through the medium of the genetically oldest sense organs that are common to the animal kingdom.

This is an expression of confidence in the all but untouched and certainly unfathomed possibilities in human learning, and also in the zeal of men of science to pool their energies and their acumen regardless of artificial boundaries between physics and psychology.

THE INTELLIGENCE OF DELINQUENTS IN THE LIGHT OF RECENT RESEARCH

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Lombroso's theory of a criminal class distinguished by definite physical stigmata is no longer held by scientists. It has been supplanted, however, by an equally simple and not dissimilar theory —the theory that a large percentage of delinquency is due to inborn mental weakness, measurable by psychological tests. The tendency among advanced thinkers to-day is to make responsibility a matter chiefly of intelligence. It is held that a large percentage of delinquents are too defective mentally to distinguish right from wrong. These should therefore not be punished, but segregated permanently in institutions where they will be given humane professional care. Thus they will be prevented from harming society either through committing further crime or through leaving offspring who because of inherited mental defect would be potential delinquents. It is held that the menace to society from these defective delinquents is all the greater owing to the circumstance that they are *high-grade feeble-minded* (morons) and therefore not superficially distinguishable from the ordinary population.

It is men of science who have furnished these generalizations, on the basis of which sociologists and zoologists, physicians and judges, journalists and men on the street defend their conviction that mental deficiency is a very important, if not the chief cause of delinquency. Dr. H. H. Goddard, one of the best-known psychologists in the United States, has been a pioneer in the development of mental testing and has fathered numerous experimental investigations of delinquency. He says in a book published in 1915: "The best estimate and the result of the most careful studies indicate that somewhere in the neighborhood of 50 per cent. of all criminals are feeble-minded. . . . Careful studies have shown beyond the peradventure of a doubt that at least two thirds of these mental defectives have inherited their defect."[1] Professor L. M. Terman, in 1923 president of the American Psychological Association, said in a book published in 1916, "There is no investigator who denies the fearful rôle played by mental deficiency in the production of vice, crime and delinquency."[2]

In view of such pronouncements as these by authorities in the field, it is seen to be inevitable that juvenile court judges and others who deal with delinquents should have their present attitude —should be always ready, upon the slightest indication, to infer mental defectiveness in their charges. Nor is it surprising that educated people in general should so readily associate delinquency with innate defect, should even be alarmed about the possible fate of a society which harbors innocent-looking individuals whose hereditary defects may cause them at any time to commit anti-social outrages. Truly, if half the delinquency in society is the result of inborn mental defect, it *is* time we looked to the quality of our human stock!

[1] Goddard, H. H., "The Criminal Imbecile," Chapter VI.

[2] Terman, L. M., "The Measurement of Intelligence," Chapter I.

It is my primary purpose in this paper to show that this whole modern attitude is grounded upon an error—one of the most regrettable, I believe, in the history of the new biological science of psychology. The social workers are sincere, the judges fair-minded, the average educated person intelligent. But they are all misinformed. Psychologists as well as many outside the field have been guilty of over-hasty generalization, of an over-zealous attempt to apply prematurely the findings of a science yet in its infancy, findings that should have been given to the public, if at all, as purely tentative. They realize their mistake now—the natural progress of scientific work has resulted already in a profound modification of the early generalizations, and the scepticism of the many psychologists who were critical from the first has been justified.

In order to understand the present status of the experimental investigation of the intelligence of delinquents, it is essential to know why and how this modification in psychological thought about the problem has come about. I shall therefore first review very briefly the original methods used in developing and standardizing the tests and shall then describe briefly the main developments of the mental testing movement, in their relation to our problem.

The chief tests used have been the Binet-Simon tests, invented in 1905 by Binet for the purpose of selecting backward children in the public schools of Paris. These tests had the advantage over the miscellaneous tests previously used in laboratories of being organized as a system, with standards of performance set for each age of childhood. There were a large number of simple tests—questions to answer, puzzles, stories to interpret, numbers to repeat and the like. The method of fixing the age standards was as follows. Quite a number of children of a particular age, say eight years, were given the tests, beginning with the easier ones. It was then determined what was the average number of tests these children passed successfully. Assuming this particular group to be typical of eight-year-old children in general, a certain range of achievement on either side of this average was set as being the normal range for eight-year-olds. Hereafter any eight-year-old child whose test record fell within this range was said to be normal. If his score in the tests was the same as the average score for the standard group, he was said to have a mental age of just eight. For every test he passed, a certain fraction of a year's credit was added to the mental age already earned. If a child failed to pass enough tests to reach the previously determined standard range, he was said to be under age, or below normal mentally. Thus a given eight-year-old child might be able to reach only the six-year average, and no higher. He would then be said to have a mental age of six or to be two years retarded mentally. If a child succeeded in passing tests above the standard set for his age, he was said to be over age, or mentally above normal. For instance, a particular child of eight might succeed in reaching the nine-year average. He would then be said to have a mental age of nine.

In the original edition of the tests as published in 1908, *there were no tests for adults*—that is, none above the thirteen-year level. It would follow that a person who passed all the thirteen-year tests could not be fairly compared with the standard group, for there would be no means of telling how much higher he might be able to go. There were found to be other disadvantages and defects, arising chiefly from the fact that the number of children of each age originally tested in determining the normal standard of performance was too small, and the children apparently not representative of children in general, but of a particular selected group or class.

Binet tried to remedy some of these defects in another revision published in 1911. This revision included tests for fifteen-year-olds, and another group for adults. In commenting on it, Binet showed that he realized clearly its tentative character, and especially its inadequacy for adults. In the same year he died. Before the close of that year Dr. Goddard, who had already been responsible for the introduction into this country of translations of the two early editions, published a new revision of his own, which we will refer to as the Goddard revision. It was better adapted for American use than Binet's 1911 edition, chiefly because of the use of more distinctively American terms, but in essentials was the same.

As soon as they were published these three early revisions found widespread use in America. It is not hard to account for the enthusiasm with which they were received. At last, it seemed, we had an objective method of *measuring* human intelligence. Moreover, the method was simple and could be applied directly toward the solution of pressing social problems. Articles on the tests flooded both technical and popular magazines. Psychologists everywhere turned from sterile problems of the laboratories to work feverishly with the new tests. Doctors, teachers and social workers also used them, for they were so simple that it seemed they could be given by any one. And so before they were carefully worked out or standardized they were applied wholesale, not only to school children, but to special groups of adults, as foreigners, Negroes and inmates of reformatories and prisons.

The first results of the application of the tests to delinquent and criminal groups were "astounding." They indicated percentages of feeble-mindedness in such groups, varying roughly from thirty to ninety. Instead of trying to interpret these figures with the caution which the hasty and unscientific character of the work demanded, sociologists and psychologists alike accepted them at face value as throwing a flood of light on the problem of delinquency.

As a matter of fact the whole of this earlier work is to be looked upon with suspicion. The conclusions are utterly unreliable. Why? In answering this question we may class all the early editions together, for they suffered from the same general defects.

Why? In the first place the tests were insufficiently standardized. Since everything depends upon the relation of the mental age earned to the standard for a particular age, it is clear that a number of *unselected* individuals of each age should be tested in fixing this standard. But only a very few were actually used, and these were not, in general, typical groups representing the whole population. This is especially true of the adults. Also, there were not nearly enough tests provided for adults. As a result of this incomplete standardization it soon became evident to the trained psychologists who used the tests that for one thing the tests for the upper years in the scale—eleven, twelve, thirteen, fifteen and adult—were *much too hard*. This point has great importance for our problem. According to the standards used by Goddard and most of the workers in this country, adults with a mental age of eleven were considered to belong in the class of high grade feeble-minded. Many investigators put all with a mental age of twelve or less in or below the same class. Now the great majority of the delinquents tested were either adults or "children" in the teens. Hence it is clear that it is just the age standards found to be too high which would be applied to delinquents, who would thereby be placed at a great disadvantage. Since we have no means of determining exactly what these delinquents might have been able to do had the tests

been carefully standardized, it is clear that the only scientific attitude is to consider the results worthless as far as quantitative statement is concerned. This point of over-difficult standards for the upper ages is only one of many defects which made the results unreliable, but it is the outstanding one for our problem.

A second reason why most of the early results are unreliable is the fact that methods of giving, scoring and interpreting were far from uniform. This lack of uniformity is partly due to the fact that three different scales were used, partly to the absence of a single standardized procedure, and partly to mere carelessness.

Even if the tests themselves had been perfect measures of intelligence, and the procedure carefully standardized, we would still find it necessary to cast out of court much of the early work. This is because in a great many cases the investigations were made by inexperienced or poorly trained examiners, who had no conception of scientific method—by teachers, social workers, students, doctors—by any one interested. The interest usually betokened a bias, and the methods and interpretations could not but be influenced by that bias. Yet strangely enough there was little discrimination among investigators, even on the part of psychologists.

Some psychologists, however, questioned from the first, and as time went on the volume of criticism increased. The first step was in the direction of establishing accurate standards by testing many *normal* people. Attention was concentrated on children first—not for years were the tests given systematically to any large number of normal adults. Yet people went on talking confidently about the low intelligence of adult delinquents, as if it were possible to state how much less intelligently these handled the tests than normal adults, before any normal adults had been tested.

Scattered testing of adults, however, soon began to arouse suspicions as to the accuracy of the adult standard. For example, Dr. J. E. W. Wallin gave the Goddard 1911 revision to some respected and successful Iowa farmers. All were rated according to the tests as middle or high grade feebleminded![8]

The results of the early testing of delinquents, then, are utterly unreliable. Yet we must remember that it is on precisely these results that our present attitude toward the intelligence of delinquents is largely based. Scientific research is often centuries ahead of popular opinion, but we sometimes forget that it is also many years ahead of ordinary cultured or semi-popular opinion. There are even scientists who have not yet had a vision of the tentative science of the future, the science which will consider the publication as truth of a hasty generalization to be a more heinous sin than perjury or murder.

Finally, in 1916, Professor L. M. Terman published a complete new revision of the Binet tests, with procedure carefully standardized and age norms much more reliable. He had added more adult tests and changed the method of scoring in such a way that adults were not so heavily penalized. Gradually the new revision has come into general use. When it is applied to delinquents it is found that the percentage of defectiveness as measured on this scale is markedly less than had been found when the old standards were used. This is because, the upper tests being less difficult than before, a person tested can make a higher mental age than he could have made on the older scales. Now, instead of percentages of feeble-mindedness ranging from 40 to 90, investigators report such percentages in reformatories and prisons as 30, 15 and 25. Yet here, as prevailingly before, all adults having a mental age of eleven or under are considered probably feeble-minded.

[8] Wallin, J. E. W., "Problems of Subnormality," Chapter 2.

With the publication of the newer results based on the Terman scale many psychologists began to revise their conceptions of the relation of defectiveness to delinquency. But they still considered it an important factor, though a less important one than they had supposed. More conclusive evidence, however, was soon to force them still more radically to revise their opinions.

With the publication of the complete results of the testing in the United States Army, in 1921, the status of our problem was again altered. Terman, taking the average performance of thirty business men and thirty-two high-school students as typical of the adult population of the United States as a whole, had fixed upon the mental age of sixteen as the average adult standard. But when his own scale was applied to 653 unselected adults in the army, it was found that they had an average mental age of only about thirteen. Ninety-three thousand men, constituting a sample of the entire white draft, were given tests similar to the Terman-Binet tests. Their scores were expressed in terms of mental age, and it was found in their case also that the average mental age was about thirteen. Plainly this means that even the Terman revision still heavily penalized the average adult. The whole white draft, or even the 653 men, of course are a much fairer sample of the general population of the United States than Terman's 62 business men and high-school students of California. Possibly the intelligence of the draft is slightly below that of the general population, for the draft did not include many officers previously sent to special training camps. This is offset, however, by the fact that men obviously feeble-minded were not included in the draft either, and so it is generally recognized that if the average test performance is any lower than would have been that of the total population, it is so only to a very slight extent.

The army figures, interpreted according to the Terman standards, would mean that the *average* citizen of the United States (if we consider the white draft as a representative group) is just above the upper line of "borderline deficiency, often classified as feeble-mindedness" (Terman).[4] They would mean that approximately 20 per cent. of the general population of the country is definitely feeble-minded, or of still lower intelligence, and that about 25 per cent. classify as borderline deficients. These figures afford no basis whatever for continuing to assume a relatively larger proportion of mental defectives among delinquents than in the population as a whole. Few workers with the Stanford scale have found among delinquents higher percentages than these.

Interpreted according to early standards, still widely prevailing, let us remember, from 30 to 47 per cent. of the white draft, and hence about that percentage of the entire population of the country, would be called feeble-minded!

When we consider what would happen even to the more recently gathered Terman data on defectiveness among delinquents were the army standards applied, we can see that the percentage of feeble-mindedness estimated to exist would have to be greatly reduced, and can fairly conjecture that it might even be negligible. So far there has been practically no direct application of the new standards, but results obtained by the older method of scoring are now being interpreted in the light of the new findings, with the result that percentages of feeble-mindedness (as measured by the tests) found even in institutions are very much lower than prevalent publications would indicate. As an example, the average mental age of 447 delinquent women confined in certain institutions in

[4] Terman, L. M., "Measurement of Intelligence," Chapter VI.

New York State was found by Fernald, Hayes and Dawley (1920) to be 11.8, which is four and a half years less than the average mental age assumed by Terman. But it is only one and a half years less than the average mental age of the army group. According to Terman's standards, the delinquent women would appear to be strikingly inferior in intelligence. Fernald, Hayes and Dawley, however, conclude conservatively: "With regard to intelligence, all indications are that the group of delinquent women is somewhat inferior to the general population, though *the difference is slight and the overlapping large,*" (italics mine).[5]

Investigations recently made with the use of the Army Alpha tests (the same general type as the Binet, but devised for group use) would indicate no higher percentage of mental deficiency among the inmates of penal institutions than in the army. The Army Report (1921) shows that the 3,300 inmates of Leavenworth Prison made a slightly higher average score in the Alpha tests than the 94,000 men of the white draft.[6] Murchison (1920) gave the Alpha tests to 3,328 white criminals, and found them to have exactly the average intelligence score made by the white draft.[7] Recently (1924) more extensive research by Murchison has abundantly corroborated this work.[8] Other investigators report similar results.[9]

Thus when we apply to ordinary non-delinquent adults the same standards that we have been using for the study of delinquents, we find among them also nearly or quite the same amount of defectiveness as in delinquent groups. Now it is patently absurd to call from 20 to 40 per cent. of our population feeble-minded. We have clearly no right to say that a mental age of eleven or so indicates probable feeble-mindedness, when a large percentage of our adult population whose mental age would be no higher are known to be fully capable of keeping their place in society. They do not meet the ordinary definition of a feeble-minded person, as being one who is "incapable, from mental defect existing from birth or from an early age, of . . . managing himself and his affairs with ordinary prudence.[10] It has been assumed that the "high-grade moron," found in such large numbers in our institutions, is *incapable* of knowing the quality of a criminal act, that he is too stupid to form moral judgments. If the delinquent moron is to be relieved of responsibility on this score, then certainly the non-delinquent moron should similarly be absolved from allegiance to moral standards, and perhaps 47 per cent. of our population should be treated as children.

It is true not only that the "morons" among us show little tendency to delinquency, but it is also true that of those who in recent years have been confined in such large numbers in institutions, a great many, after discharge, have proved themselves capable of leading ordinarily happy and efficient lives in society. Follow-up observations on former inmates of the institution for the feeble-minded at Waverley, Massachusetts, furnish a case in point.

Such considerations as the above make it glaringly evident that our standards for interpreting the testing of delinquents are wrong. We psychologists will

[5] Fernald, Hayes, Dawley, "A Study of Women Delinquents in New York State," 1920.

[6] Memoirs National Academy of Sciences, 1921, Vol. XV, p. 800.

[7] Murchison, Carl, "Criminals and college students," *School and Society*, Vol. XII, July 3, 1920.

[8] Murchison, C., "American White Criminal Intelligence," *Jour. Criminal Law and Criminology*, 1924, Vol. 15, pp. 239–317, 434–494.

[9] See Pintner, R., "Intelligence Testing," 1923, pp. 288–293; also Gault, R. H., "Criminology," *Psychological Bulletin*, Oct., 1925 (summary with bibliography).

[10] Quoted from formulation of the British Royal Commission on the Feeble-minded (1904).

have to make many more careful investigations in the light of the newer standards before we can offer even an approximately reliable numerical estimate of the percentage of feeble-mindedness or mental deficiency as measured by tests among delinquents in institutions. Already, however, we have scientific proof that the earlier and still prevalent estimates were greatly exaggerated, and there are clear indications that the percentage of feeble-mindedness in the whole delinquent group may be only slightly greater, possibly no greater, than the percentage of feeble-mindedness in the population as a whole.

At the beginning of the testing movement tests poorly given and illy interpreted gave unfortunate impetus and direction to a strong popular conviction. But we must remember that more of the same kind of tests, well given and carefully interpreted, have now given us sure grounds for questioning that conviction. It is not the method but its use which was at fault. Without tests we should be again lost in a hopeless maze of speculation. It is through their aid alone that we can hope to make progress toward the attainment of positive and objective knowledge about the intelligence of delinquents.

EARTHQUAKES[1]

By Commander N. H. HECK

U. S. COAST AND GEODETIC SURVEY

WHENEVER man begins, in any field, to think that he has at last succeeded in the constant struggle with nature, he receives a reminder that when nature sees fit to put forth her whole force his best efforts are helpless. He builds a *Titanic*, and an iceberg sends it to the bottom of the sea; a town is built near a volcano, and all living beings are silenced in a single breath; a tornado sweeps across a city and the best built structure falls before it. There is, however, nothing which brings the feeling of helplessness to large numbers of men more than a severe earthquake. Something happens in the interior of the earth, waves move along the surface and the surface of the earth itself may be torn apart; that surface on the stability of which men base all their plans. Their buildings may fall or be seriously damaged or given over to the unrestrained activity of another force of nature—that is, fire.

In the United States we are interested in earthquakes at the present time because a number have occurred during the past year and a large area of the country has felt earthquake shocks. Fortunately many of these were not severe and the others were not of the most severe type. What is an earthquake? There are a number of answers to this question, but for the moment we will consider that as a result of a shock in the interior of the earth waves roll along the surface. These waves have been actually seen at times. They are somewhat like those at sea, but near the earthquake center they are usually more confused than sea waves. A solid surface like the earth, in many cases, is too rigid to take the form of the waves, and in such a case the surface may be broken apart, leaving chasms, though frequently the waves pass along without fracturing the surface. The reason that the earthquake waves do damage to buildings is largely because they are not built to stand the peculiar strain. As a wave passes along, the bottom is tilted in one direction, while the top is a little delayed in responding to the tilt. The bottom is then tilted in the other direction, and there is again delay on the part of the top; the result is that not only is the building severely racked at all its joints, but a vibration is set up so that unless the building is strong enough to act as a whole it may be entirely shaken down. An example of the worst type of building for an earthquake region is found quite commonly in Japan. Heavy tiles are placed on a light structure; when the earthquake comes the structure begins vibrating and in itself would stand the earthquake very well, but the roof breaks apart, the tiles start to fall and kill any one caught within the building. This was a cause of serious loss of life in the 1923 earthquake in Tokyo.

The earthquake waves in many cases are not regular like the waves which roll in on the beach at the seashore. This has been proved by a study of the direction in which statues fell in one of the great earthquakes in Japan. Near the center of the earthquake statues fell in every conceivable direction. In other

[1] Broadcast from Station WRC, Washington, October 29, 1925, under the auspices of the Smithsonian Institution and the direction of Mr. Austin H. Clark.

places there was a general direction to their fall, but many did not fall in the same direction as the others. These confused waves may put very varied strains on buildings, and only those of the best material, properly fastened together, will stand.

The passing earthquake waves have, in some cases, left some very interesting traces. In 1906, during the California earthquake, a railroad train was turned over on its side, while the rails and the bed of the railroad showed little trace of disturbance. In this case the crest of the wave was parallel to the railroad track. The train was tilted over, just as a ship rolls as the crest of a wave passes. We have an example, however, in the Charleston earthquake of 1886 and in several in Japan that when a wave passes along diagonally to the railroad track it twists the rails into S-shaped curves going off into the distance. In certain formations the earth itself may remain in the form of the passing waves until the rains finally level it to its former condition.

At times chasms open in the earth. In the recent earthquakes in Montana, near the town of Three Forks, cracks several feet wide and a number of feet deep opened in a roadway and remained. The story is told of a case in California where a crack opened and a cow dropped in. The crack then wholly closed and the only evidence left was the cow's tail sticking up out of the ground. Whether this incident is true or not, it is true that the cracks often close after the earthquake is over. It is quite clear that when such cracks occur below a building, damage will result, no matter how well it is constructed, but these occurrences are comparatively rare.

Perhaps even more effect on the earth's surface results indirectly from earthquakes by the setting off of landslides. In the case of the earthquake of 1906 in California, in San Francisco where the earthquake was severe, more damage was done by the starting of fires and preventing their extinction than by direct action. Insofar as the surface of the earth was concerned, the effect was much greater north of San Francisco, in a relatively unsettled region, where numerous landslides occurred. During the recent Montana earthquake, landslides occurred which caused some damage and inconvenience in railroad operations. Some years ago in western China, a great earthquake occurred which caused landslides on an enormous scale. The earth happened to be of a peculiar formation and was apparently water-soaked at the time. As a result, the landslides were so vast that a section of a road was carried nearly half a mile. It was stated that a great many caves were buried in these landslides and that these caves were largely occupied by priests of the Mohammedan religion. So many of these priests were buried that the non-Moslem Chinese said that this was an indication of the falsity of the religion. Furthermore, a serious rebellion was suddenly brought to an end, for the leading general and all his staff were caught in the collapse of one of the caves.

The damage to buildings and changes of the earth's surface are nearly always confined to a certain region which may be large or small, according to the earthquake, but the earthquake waves thus set in motion do not stop at the edge of this region but usually travel for long distances, in some cases around the earth, and in rare cases twice around the earth. When the central region has been left these tremors, as they are usually called, can be detected only by instruments. Such tremors occur in Washington quite frequently, as is evidenced by the records of the seismographs at Georgetown University and at the magnetic observatory of the Coast and Geodetic Survey at Cheltenham, Maryland,

eighteen miles south of Washington. Even if we can not feel these tremors, the recording of them is of great importance in the study of earthquakes. With good records we are able to find out where an earthquake occurs, even if it is out in a desert region with no inhabitants or if it is under the sea. The details of the method, while not very difficult to grasp, are perhaps not appropriate to a radio talk, so I will give you an illustration in order that it may not seem entirely mysterious. Suppose that you stood on the edge of a pond and that on the other side some one threw in a pebble when you were not looking. You would see the approaching ripples and could tell from what direction they came and so could face the place where the pebble struck the water. Now suppose that another person did the same thing at a point on the edge of the pond some distance away. You would both be facing the point from different directions so that it would be possible for you to direct a man in a boat to drive a pole into the bottom at the point toward which you were both looking. The pole would undoubtedly be quite near the pebble resting on the bottom, even though neither of you had seen it strike the water.

In the case of earthquakes there is a method which gives the direction, but it is easier to find the distance from the earthquake to the place where the seismograph is established, and by knowing the distance from several stations we can readily compute the place where the earthquake occurred. You have frequently seen reports from Georgetown and other universities in which it was stated that a certain earthquake occurred a certain number of miles from Washington in a given general direction, but usually this is all that a single station can do. In some of the more important earthquakes, in accordance with arrangements made by Science Service, telegraphic information, in code, is received from a number of stations and then the United States Coast and Geodetic Survey works out the position and within a day after the occurrence states definitely where the earthquake occurred. Recent examples have been an earthquake off the coast of Kamchatka and another in Honduras.

There are many theories as to the cause of earthquakes, but none has been absolutely proved. It is known, however, that there are actual breaks in the earth's crust at certain places, and that such breaks have usually resulted from strains in the earth's crust. In many cases the strains have continued and they are relieved usually only by slipping along the break. When the slip occurs suddenly, an earthquake is almost sure to result, and then the waves are sent out in a way similar to that when a pebble strikes the surface of a pond. The forces involved in an earthquake are very great, but in many cases an earthquake may be set off by a small force. This force does not, in any way, cause the earthquake, but it does determine the instant when it occurs.

As an example of this we know that at times large buildings have failed by the falling in of the roof. It is not impossible that such a roof could be so delicately balanced that it would be ready to fall for several days and then a very slight force, such as the vibration of a passing truck, could fix the exact time for the fall. In the same way, the slip which produces the earthquake can be ready to occur and the exact instant will be fixed by such a cause as a change in barometric pressure due to a passing weather disturbance, a heavy shower, melting snow or an exceptionally high tide on the coast. None of these in themselves could cause an earthquake, but any of them may determine exactly when an earthquake, otherwise ready, will occur.

You probably would like me to tell you whether or not there is going to be a severe earthquake in the United States in the near future. No one can answer this question. We have had severe earthquakes across the Maine border in Canada and in South Carolina, in the east; in the upper Mississippi Valley in the middle west; in the Mountain States and the adjoining parts of Mexico; and on the Pacific Coast. The probability of a severe earthquake in the east or middle west is small, but not too small to ignore. In the past each period of earthquake activity has developed great interest which has quickly disappeared after a short period. I hope that this time a program will be fully established so that not only will we have more information when the next earthquake occurs, but we will begin to understand the laws governing earthquakes.

There are many indications that we are now beginning to go at this problem in the right way. The government, through the Coast and Geodetic Survey, is operating seismographs, collecting information about earthquakes and publishing the results in useful form, and will do more of this as time goes on. The Weather Bureau helps in collecting earthquake reports for the United States when the earthquakes are felt. The Geological Survey examines regions where earthquakes have occurred. Many of the universities and colleges are operating seismographs, and in this matter the Jesuit institutions are especially active. You are probably aware of what is being done by Georgetown University here and Fordham University in New York. Of this group, St. Louis University is about to start investigations in the Mississippi Valley in the region where a great earthquake occurred many years ago. The Carnegie Institution of Washington is, with the cooperation of the government and various institutions, directing a detailed investigation into local earthquakes in California. National organizations of architects, civil engineers and builders are studying codes and methods of insuring safer buildings and other structures in earthquake regions. The fire insurance companies are especially interested in the prevention of loss by earthquake, and there are many signs that activity in earthquake investigation is now starting upon a sound basis in the United States, and it will go on until we have learned more about how to meet earthquake danger in this country and the rest of the world than we have heretofore.

PERPETUAL MOTION IN THE TWENTIETH CENTURY[1]

By Dr. PAUL R. HEYL

BUREAU OF STANDARDS

It is an eloquent comment on the extent to which the twentieth century has modified our traditional physical concepts that it should be possible for a scientific man (otherwise in good standing) to submit an essay on perpetual motion to the SCIENTIFIC MONTHLY and that it should be accepted and published. Such being the case it behooves all of us who profess and call ourselves physicists to examine with care the foundations of our traditional belief in this matter.

Prior to the introduction of the concept of energy and the formulation of the principle of its conservation it was indeed generally believed that perpetual motion was impossible; but this belief rested not upon any general principle but on the fact that a careful examination of every proposed device of this character disclosed some flaw. It is probably true that this examination of individual cases played its part in bringing about the recognition of the general principle that the creation of energy was impossible. Once well established, the principle of the conservation of energy became a closed door against which inventors of perpetual motion machines knocked in vain, unable to obtain a hearing.

A little later came the statement of another general principle—the second law of thermodynamics. This asserted, in brief, that heat could not run up-hill of itself; that if a hot body was placed in contact with a colder one the tendency would be to equalize their temperatures, not to increase the difference.

For this down-hill tendency no specific reason was at first assigned. As originally formulated by Clausius, the second law was purely empirical, an appeal to experience, and as such, as Clausius himself says, it did not find a ready acceptance in the minds of other persons.[2] The analogy of the down-hill flow of water was imperfect, for there the governing influence of gravitation was evident, while in the case of the flow of heat there was no recognizable controlling force. That heat usually *did* flow down-hill was an admitted fact; but that it always *must* was, in the minds of many, an open question. Schuster says[3] that about 1875 both Balfour, Stewart and Wien had such doubts as to the generality of the second law that they were experimenting (independently) in the hope of finding a case where it would break down.

Perhaps they were influenced in this by Maxwell, who about that time showed that the operation of the second law could be suspended by the interposition of intelligence.[4] His famous concept of "sorting demons" is well worth study to-day. He showed how, given an intelligence able to handle and sort single

[1] Published by permission of the director of the National Bureau of Standards, of the U. S. Department of Commerce.

[2] Clausius, "Die Mechanische Warmetheorie," 3rd edition, 1887, p. 82: "Dieser von mir als Grundsatz hingestellte Satz hat viele Anfechtungen erfahren."

[3] Schuster, "Progress of Physics from 1875 to 1908," p. 22.

[4] Maxwell, "Theory of Heat," 1875 edition; Appendix, "On the Limitations of the Second Law of Thermodynamics."

molecules (and we have made a long step toward realizing this since Maxwell's day), it is possible, without expending any work or violating the principle of the conservation of energy, to warm one half of a mass of gas by cooling the other half—in other words, to make heat run up-hill.

The work of Boltzmann and of Planck during succeeding years did much to place the second law on a more satisfactory basis—one of probability. Boltzmann showed that the spontaneous equalizing of the temperatures of two bodies was in effect merely the passage of the molecules of these bodies from a less probable to a more probable arrangement. The hypothetical flow of heat up-hill was thus seen to be not impossible, but merely improbable.

An example will illustrate this point. The law of gaseous diffusion is closely similar to the law of flow of heat, diffusion always tending toward a state of uniformity. Differences in density, like differences in temperature, if left to themselves, tend to disappear rather than to increase. It would be just as surprising to see a gas, originally of uniform density, crowd itself spontaneously into half the volume, leaving the other half a vacuum, as it would be to see heat run up-hill.

Suppose a volume of gas so small that it contains but two molecules, one in each half of the volume. These molecules are continually in motion, rebounding from the containing walls and passing back and forth irregularly from one half of the volume to the other. We may have four possible different arrangements:

A	B
B	A
AB	
	AB

Of these four possibilities, two represent a vacuum in one half the space. The probability of such an occurrence is therefore 1/2, that is, it may be expected to occur half the time.

As the number of molecules increases the probability of a vacuum arising in this way decreases rapidly. For a total of n molecules the probability that half the volume will be empty is $\frac{1}{2}^{n-1}$, which, for the enormous number of molecules ordinarily dealt with, is to all intents and purposes zero. For the much more probable case that the pressure in the two halves of one cubic centimeter of a gas should differ by one per cent. the probability is still so small that such a condition may be expected to arise spontaneously only about once in $10^{10^{18}}$ years!

One point needs emphasis in this connection. If an occurrence is so rare that it may be expected to happen on the average once in an eon, it must still be borne in mind that it does not necessarily follow that we will have to wait that long to see it happen. There is nothing to prevent it happening at the end of the next five minutes; the probability of that is exactly the same as the probability that it will happen at the end of an eon. It might even occur twice in the next minute; but if it did it is possible that time itself might not be long enough for it to happen again.

A similar line of reasoning leads us to an analogous conclusion with respect to the possibility of the spontaneous appearance of temperature differences. The temperature of a gas is determined by the velocity of its molecules. In a gas at what we consider constant temperature the velocities of the individual molecules are far from being the same, but are distributed about a mean which remains constant. Consider a volume of gas so small that it contains only four molecules, two equally fast-moving ones, F_1, F_2, and two equally slow ones, S_1, S_2. The various possibilities of arrangement (assuming that there is no change in density) are six in number:

$F_1\ S_1$	$F_2\ S_2$
$F_2\ S_1$	$F_1\ S_2$
$F_1\ S_2$	$F_2\ S_1$
$F_2\ S_2$	$F_1\ S_1$
$S_2\ S_1$	$F_1\ F_2$
$F_1\ F_2$	$S_1\ S_2$

Of these six possibilities the first four represent cases of equal temperature in the two halves of the gas, for our temperature measuring instruments can give us only a mean value. The last two, however, represent differences of temperature, the probability of which (for four molecules) is consequently 1/3.

With an increase in the number of molecules the probability of any large difference of temperature resulting in this way becomes rapidly less; yet we must recognize that in any volume of gas that we can handle the temperature of any and every small portion is continually and imperceptibly fluctuating up and down, and that on the whole the gas is no more uniform in temperature than the surface of the ocean is absolutely level.

That sensible differences of temperature may arise in this way is, of course, highly improbable, but not impossible. We must, however, recognize the fact that heat not only *can* run up-hill, but that it is continually doing so on a very small scale; and that perhaps once in a blue moon we might actually observe it.

We can now understand that hard saying attributed to Planck: that if a kettle of water be placed on the fire there is a chance, though an exceedingly small one, that the water will freeze!

Once it was recognized that up-hill changes in temperature and density were continually occurring on a very small scale, the question was raised whether it was not possible by some device to accumulate these changes until a sensible effect could be produced and useful work obtained. Such a device may be called a perpetual motion machine of the second kind, as it obtains work not by a creation of energy, but in spite of the second law of thermodynamics.

Several such devices have in fact been proposed by Lippmann, of Paris,[5] and Svedberg, of Upsala.[6] In 1912 Smoluchowski[7] published an extended discussion of the theory of the subject and as a result laid down the general principle that we can hardly hope to accumulate these departures from the second law on a molecular scale by any device built up of molecules; for every such device is itself subject to molecular variations which, in the long run, will probably cancel out the variations that we hope to pick up by its aid. Smoluchowski's argument, however, is not final, but only discouraging.

Be this as it may, it is sufficiently novel and surprising to recognize that the second law can be said to be valid only in a statistical sense, in the long run; yet twentieth century thought is already pushing still farther and hinting at the possibility (on a molecular scale also) of perpetual motion of the first kind—the actual creation of energy; for Professor Debye in a recent address[8] has warned us that in order to reconcile the phenomena of interference with the quantum concept it may be necessary to assume that the conservation of energy itself is true only statistically; that energy may be created and annihilated, in minute fluctuations, its average remaining constant in the long run. What will be the outcome of this, no one can as yet say; but it is possible, in these iconoclastic days, that this doctrine may sooner than we think become unimpeachably orthodox.

[5] Lippmann, Rapp. du Cong. Int. de Phys., Paris, 1900; Vol. 1, p. 546.

[6] Svedberg, *Zeit. phys. Chem.*, Vol. 59, 1907, p. 451.

[7] Smoluchowski, *Phys. Zeit.*, Vol. 13, 1912, p. 1069.

[8] Address at the Bureau of Standards, March 11, 1925.

THE PROBLEM OF ANEMIA

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MANY years devoted to the study of disease have indicated that certain age groups more so than others are susceptible to particular ailments. Thus in the first decade we find measles, scarlet fever and diphtheria most common. The second and third decades are characterized by the prevalence of tuberculosis; the fourth and fifth by tumors and heart defects and the sixth by arterial disease. Among the multitude of diseases which afflict human beings are many associated with blood changes designated as anemia, which is usually observed as a variable degree of pallor. The appearance of the skin and mucous membranes, however, as an index of anemia is frequently deceptive, for pale individuals may have a normal hemoglobin content and the state of the blood can only be accurately determined by mensuration with special apparatus, such as hemoglobinometers and blood-cell counting pipettes.

Anemia is properly regarded as a symptom and not a disease. The condition is most frequently seen in young and middle-aged persons and appears to be more common now than in former years. It may arise from a variety of sources, and, while physicians speak of a primary and secondary anemia, in reality there is no primary anemia or blood disease of this type, since the blood changes are always secondary to an exciting cause. The anemias associated with loss of blood or its elements within the circulation may for diagnostic purposes be divided into four main groups: (1) pernicious anemia, (2) secondary anemia, (3) aplastic anemia and (4) leukemia. This does not represent a scientific medical classification but suffices for the purpose of the present discussion. Frequently in the above groups one merges into the other so that sharp differentiation is not always possible.

Perhaps the most remarkable tissue in the body is the blood and it may rightly be considered a tissue since it consists of cellular elements enclosed in a stroma, which in this instance is the blood plasma. The blood penetrating to every part of the body acts as the great medium of exchange, carrying to the tissues oxygen and the necessary food elements and removing to the excretory organs the waste and harmful products. It will thus be appreciated that the blood, although possessing marvelous powers of adjustment, is exposed to injury from a great many sources. The air we breathe when vitiated by a harmful gas leaves its impress on the blood; injurious substances may be absorbed through the skin and even the food and fluid we take may, if unsuited to the individual, be productive of undesirable haemic changes. If the efficiency of the blood is impaired, then all the organs of the body suffer in proportion precisely as the crippling of a transportation system has a demoralizing effect on the activities of an entire community. Small wonder then that anemia is so common when one considers the many avenues by which the blood may be attacked.

Most existing illness is due to infec-

tions, and infections, either acute or chronic, are invariably associated with some degree of anemia. These infections may be very evident in their onset and progress and again may be so insidious as to remain unrecognized until the patient is quite ill. The natural tendency of most disease is toward self-cure, but many diseases do not so terminate and repeated trauma to the blood may result in mortal injury to that tissue and its formative organs. The blood, after a fashion, also acts as a solvent for poisonous substances which may accumulate in certain organs, causing great damage there, while the blood itself shows but little change. The circulation also acts mechanically in transferring bacteria from one point to another.

The blood is a highly complex fluid, but in the condition of anemia our attention is directed to but one element—the red blood corpuscle or erythrocyte. This minute cell, thirty-two hundredths of an inch in diameter, is a biconcave or cup-shaped disc consisting of a very thin membrane enclosing a protein material, namely, globulin, in which is found the iron-containing pigment or hemoglobin. The cell has a faint straw color, but in bulk or by reflected light appears red. The erythrocyte is exceedingly pliable and is without a nucleus, thus being unlike all other body cells. In its developmental stages the red blood cell possesses a nucleus, but this is lost when the cells enter the circulating blood after birth and the appearance of nucleated red cells in the post-natal period is distinctly pathologic. The blood elements are readily examined microscopically in the fresh state, but when spread on glass in the form of a thin film and stained with certain combinations of aniline dyes the cells appear more clearly defined and any intracellular structure or parasite becomes visible. The cells are inconceivably numerous, and as well as can be determined there are approximately 5,000,000 to each cubic millimeter of blood. Their large numbers thus permit of an enormous absorbing or oxygenating area.

The structure of the red blood cell is not clearly understood. There appears to be an outer limiting membrane and a framework or stroma holding in its mesh the hemoglobin. The function of the hemoglobin is to act as an agency for the transfer of oxygen and carbon dioxide. Within the cell are also salts, cholesterin and lecithin, which appear to exert an important function in retaining the hemoglobin within the cell membrane. The outer limiting membrane is a homogeneous structure, colloidal in character, and permits free passage of osmotic currents. The red cells maintain their shapes in the serum or in physiologic salt (0.85 per cent.) solution, but when placed in concentrated salt solution the cells shrink or if the salt content be decreased the cells swell and finally rupture, allowing the hemoglobin to escape. Recognition of this fact is of extreme importance in routine hospital work, where solutions are so often introduced directly into veins.

The fundamental facts that bacteria are responsible for infection and that the symptoms induced are due to toxins generated by the bacteria are now universally recognized. Regardless of what part of the body is infected the toxins are absorbed by the neighboring blood and lymph vessels and distributed to all the tissues and organs. Some bacterial poisons have a selective affinity for certain tissues or organs. Thus the toxins of tetanus and polioencephalitis attack the nervous system; of syphilis, the vascular system; mumps, the parotid glands; smallpox, the skin and mucous membranes; streptococci, the blood and bone-marrow. Similarly, we find chemical poisons exerting a selective action. Lead affects the blood and nervous system, phosphorus and copper the liver

and bichloride of mercury the kidneys. Disorders of metabolism, malnutrition, scurvy and rickets are all associated with varying degrees of anemia, and the blood changes of anemia are a pronounced feature of all malignant tumors.

It has been previously stated that most illness is due to bacterial infections, and the majority of these are of a chronic nature. Virulence of the infecting agent and resistance of the body are extremely variable factors. After the first onslaught by bacteria with the body the victor, the microbes may yet remain indefinitely within the body leading a partial parasitic existence. Nevertheless, in this state they are constantly generating poisons of a low toxic effect, but the continuous presence of poisonous substances in the blood and organs must necessarily have a harmful action. Since the blood is the carrier of these toxins we find early changes present in the form of anemia, that is, a decrease in the number of red blood cells or of hemoglobin or both. Examination by means of special instruments shows that this alteration is brought about in two ways, either by decreased production or increased destruction of the blood elements. Certain toxins destroy the red cells, while in the blood stream others depress the bone-marrow function where the red cells are formed, thus decreasing their numbers in the circulating current. Regardless of the mechanism involved, the end result is the same and the patients present identical symptoms with reference to anemia.

By way of illustration we may consider malaria. In this infection the malarial parasite lives and develops within the red blood cell and in the process of development totally disrupts the cell. Millions of these elements are thus destroyed every second or third day faster than regeneration can take place and the resulting effect is anemia. In hookworm infestation the repeated bites of many worms in the intestine causes daily loss of considerable blood, so that after some weeks or months a distinct anemia results. The process here is similar to the steady or intermittent loss of blood from an ulcer of the stomach and experimentally an animal such as the rabbit when bled daily or several times weekly from an ear vein soon develops a profound anemia from which it may not recover even though the bleeding is not continued. In certain diseases of cattle, such as Texas fever, a parasite enters and destroys the red cells in such large numbers that the hemoglobin thus set free appears in the urine in sufficient quantity as to color it quite darkly.

A more subtle form of blood destruction also takes place. Infections due to the streptococcus group are common. Biologic study of certain members of the group shows that among other products the organisms produce a substance called hemolysin, which when brought into contact with red blood cells causes their dissolution. Similar action obtains in the circulating blood during infection by these same organisms and in the case of the more virulent strains a rapidly developing anemia ensues. A more chronic destructive action is brought about by other members of the group with resulting prolonged anemia. Many other bacteria also generate similar hemolysins of varying degree of potency and the same process is seen in exaggerated form following the injection of snake venom. The exact nature of the process is obscure but probably is dependent upon certain physicochemical activity bringing about increased intracellular pressure. Hemolysins not normally resident in a given animal's blood may be caused to appear by injecting into that animal the red blood cells of an alien species so that when the blood serum of the injected animal is brought into contact with the red blood cells of the second

animal hemolysis is produced. This phenomenon is taken advantage of in certain diagnostic tests, as in the Wassermann reaction. Many of these toxic substances also injure the endothelium, the delicate lining of blood vessels and so permit considerable loss of blood by exudation.

Pernicious anemia is the *bête noir* of physicians. Insidious in onset it is usually well established when discovered by a blood test. This examination discloses the characteristic features of the disease, namely, marked variation in size and shape of the red blood cells. Many of these are quite small, others large and pale, still others are oval, pear-shaped, tailed or appear fragmented. They are so altered that it is very apparent that the cells function but poorly. The reduction in the number of red cells and the corresponding decrease of corpuscle oxygenating surface tend to make the patient weak and short of breath upon the slightest exertion. In the fully developed disease the patients have a curious pallor, a lemon-yellow tint to the skin which is fairly characteristic of this form of anemia.

The actual cause of pernicious anemia is unknown, except in the case of infestation by the fish tapeworm (Dibothriocephalus latus). In the presence of these parasites the blood changes are typically those of pernicious anemia and death results if the patient is not relieved of the worms. The reason for the particular harmfulness of this parasite appears to be due to the fact that it secretes saponin, a substance which is hemolytic for red blood cells. But not all the infected cases develop anemia. Poisoning by toluylenediamine causes excessive hemolysis, resulting in anemia of the pernicious type and there are other chemical agents which act in a similar manner. In many instances localized bacterial infection, particularly about the mouth, appears to be responsible for the anemia. Severe cases of pyorrhea and abscesses of root sockets in which streptococci are abundant have been observed in association with severe anemia bordering on the pernicious type and that the relationship is a causal one is indicated by the disappearance of the anemia upon removal of the infection. At many points in the body collections of bacteria may exist constantly giving off substances having a hemolytic action. Many cases of secondary anemia have their origin in such hidden foci of infection.

A more unusual form of blood disease which is acute in onset and associated with infection is aplastic anemia. Here we find in the circulating blood stream a steady decrease of red and white blood cells. The loss finally becomes so great as to be incompatible with life. Examination after death discloses a marked impoverishment of the bone marrow which explains the anemia. The injury is so profound that although the exciting cause be discovered and removed the marrow appears unable to regain its function of producing blood elements. Fortunately this type of anemia is rare.

Leukaemia, a disease which appears in two forms, myeloid and lymphatic, is also associated with profound blood changes and in fact can only be accurately diagnosticated by examination of the blood. In this disease the essential features are marked increases in the various forms of white blood cells, but there is also a decrease in the red cells and percentage of hemoglobin. So augmented are the leucocytes that the condition has been likened to a tumor of the blood, for the cells appear to increase in the peripheral circulation as well as in the bone-marrow, spleen and liver. The red cells may finally become fewer than the white cells or leucocytes, and when this stage is reached the patient is usually "in extremis." Leukaemia is also associated with hyper-

plasia or overgrowth of the lymph nodes, spleen and bone-marrow, and in the latter situation it is the white cell elements and not the red that are increased.

Here, then, are several diseases of the blood with the same underlying factors —a steady loss of hemoglobin due to the escape of blood, destruction of red cells or inhibition of the blood-forming tissues. In some instances the causative factors are easily demonstrated, in others they are obscure. The mechanism of the morphologic changes in pernicious anemia is poorly understood, but it is not unlikely that they are due to alteration in surface tension. By varying the salt concentration of plasma or even by subjecting normal blood to the influence of heat one can produce distorted red cells similar to those found in pernicious anemia. The extreme delicacy and plasticity of the enclosing membrane of the red corpuscles facilitates rapid variations in size and osmotic relationships and certain abnormal factors might readily tend to "fix" the cells in their irregular forms. Such altered cells are more fragile than normal.

A few metallic poisons exert a direct deleterious action on red cells. In plumbism the erythrocytes appear pale and are reduced in numbers. Many take on peculiar staining characteristics. It is thought by some workers that the absorbed lead salts tend to make the red cells so fragile that they can not withstand the traumatism in the blood stream and consequently undergo fragmentation, the broken parts being retained in the internal organs such as the spleen and liver, where they are demonstrable on microscopic examination in the form of complete or incomplete red cells or altered blood pigment.

Thus we find that in a great variety of diseased conditions anemia is present and may be the only early evidence of something abnormal in the body. The examination of the blood indicates the form of anemia and leads to search for possible causes which in most instances are detectable. When an inflammatory process, as in a tonsil, sinus, tooth or bone, is discovered complete relief of the secondary anemia follows proper treatment of the infection. But the problem is much more serious in the other forms of anemia, where careful and repeated search often reveals no cause. Coincident with the blood changes in pernicious anemia there is in most cases a total absence of hydrochloric acid in the gastric juice, but supplying this deficiency to the patient does not cure the anemia. The real cause is still unknown and may not be the same in all instances. Secondary anemia is the most common form of blood disease, and more important than determining its presence is discovery of the cause, which is feasible in most instances and eradicable.

MODIFICATIONS DUE TO HUMAN AGENCIES IN THE MARINE LIFE OF THE PACIFIC COAST

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Modifications in the marine life of the Pacific that have been brought about by human agencies may be treated under five headings: (1) Modifications due to commercial exploitation; (2) disturbing of the balance of nature by the unequal drain on certain species by such exploitation; (3) modifications due to the changing of conditions in the sea and along the shore; (4) modifications due to changing conditions that affect anadromous species; (5) the introduction of new species.

Commercial Exploitation

As in many other instances, man's interference with the life of the sea has produced, in the main, destructive modifications. He destroys directly for his own advantage or to suit his whim, and he destroys indirectly by carrying out plans for his own profit without paying any attention to the disturbances that may result.

If toll were taken from all species alike there might be little disturbance in the natural balance, but that is not the way it works out. The species that have suffered from direct destruction are those that can be or have been put to some commercial use. They may be used as food for human beings or for domestic animals, their pelts may be used as fur or leather, oil may be extracted from their tissues or they may be used, entirely or in part, as fertilizer. Even among the species that might be used for one or more of these purposes fancy has had its fling, and in consequence the effect of man's destructive power has been borne by comparatively few species that have thereby suffered serious depletion if not complete extermination.

Apart from the matter of fancy, two things must determine what species will be sought—the total value of the commercial products obtained from one individual of the species and the cost of obtaining, preparing and distributing these commercial products. Other things being equal, the large organism will be taken in preference to the small, the gregarious in preference to the solitary, and the inshore and readily accessible in preference to the deep sea and less accessible. Many of the mammals are of such large size and may be of such high commercial value that these factors outweigh all the others combined. In general, the large species and the gregarious species have suffered to the greatest extent.

Possibly the best example of rapid extermination by exploitation on the Pacific coast of North America was that of the *Rhytina* or seacow, the largest of the Sirenia. Reported for the first time by Steller, the surgeon-naturalist, who was with Bering when his ship was wrecked on the Commander islands in 1741, this large, helpless, herbivorous animal was found to be excellent for food. It was soon hunted by the people of Siberia as well as by whalers and sealers until within fifteen years practically

all of them were killed. In 1768 the last one was reported. There were thus but twenty-seven years from discovery to extermination.

The history of the sea otter is almost as tragic if not so brief. A hundred and fifty years ago the sea otters were so plentiful along the coast, and particularly along that part west of Vancouver Island, that it was considered worth while, even in those days of slow navigation, to fit out vessels in England and Spain to sail around the Horn to trade in sea otter skins. Always valuable on account of the quality of the fur, they were slaughtered in great numbers, as they lived near enough the shore to be readily accessible. The numbers rapidly decreased, but the value of the hides increased and the hunting became more and more intense, with the inevitable result. To-day no other fur can approach the value of that of the sea otter, but there is probably not a single animal alive on the coast of British Columbia and there are very few on any part of the coast, although since 1911 they have been wholly protected.

The story is repeated in the case of the elephant seal, although since it lived in a much more restricted area, the case is not so spectacular. Only a very small remnant, let us hope that it is a saving remnant, of the species exists to-day.

The plot was laid for another similar story with the fur seal as the sufferer. The introduction and the preliminary chapters were written and staged. The quality of the fur serves as the incentive to slaughter. For a time a lack of knowledge of the periodic migration and the distant and inhospitable location of the rookeries did much to prevent rapid destruction, but soon the definiteness of the breeding season and the segregation in such large numbers at that season offset the deterrents in other directions and the annual kill became greater and greater. The climax was reached when the migration route became well established and pelagic sealing brought about an even greater drain on the fur-seal herds, partly because such a large number of pregnant females were included in the slaughter. The stage was all set for the last act, the act of extermination, but the performance was not carried out. The people of four countries, through their governments, interfered. The exploitation is now so controlled that the numbers are rapidly increasing instead of decreasing, although a considerable annual revenue is derived from them. While such sensible handling of the situation prevails, "to be continued" will take the place of "finis."

The whale, although it is so large and of such great commercial value, has been in less danger of rapid depletion, as the different species are not so gregarious as the sea cow, fur seal, etc., because they live more in the open sea and because, particularly in the case of the whalebone whales, their very existence depends on their active life in search for food. In the earlier days of small whaleboats and hand-thrown harpoons, the whale had a fair chance of holding its own, but when these were replaced by power boats, harpoon guns and explosive bombs, this chance disappeared. The only saving grace lies in the fact that modern methods are expensive and hence although some species have suffered great depletion, almost to extermination, there is not the same danger, as in other species, since, when the numbers in any area become too small, it is not commercially profitable to hunt them.

The walrus has long been hunted, and even though the methods still used are rather primitive, large numbers are accounted for. In many places where formerly they came ashore in large numbers, the wholesale slaughter has driven them away entirely. When they are hunted on the ice, there is a large economic waste, for many that are killed are not retrieved and in the case of those that are retrieved it may be possible that

only the tusks can be taken ashore. The flesh, or most of it, valuable as food, is left to decay.

The sea lion is in a somewhat different category. It has not been hunted very extensively on account of its commercial value but rather because of the damage it does to some of the established fishery industries. It does considerable damage in some localities, but the life history is not well enough known to be sure that it may not have as much to its credit as to its debit. As is commonly the case with animals in general, those who are affected by the damage done at certain times of the year have their eyes closed to any good that may be done at other times. In certain localities there has been great depletion of the species on that account, but I am not sure that the total number along the whole coast has been materially diminished since more extensive killing began.

Of the birds, the game birds, such as ducks and geese and their allies, have been killed off for food. In many areas these are much scarcer than formerly, but that this decrease in numbers is even largely due to the fact that they have been shot in sheltered waters along the coast is open to doubt. They are all migrants and they suffer even greater loss of life in other parts of their migratory course. Probably the draining of marshes has had more to do with the decrease than any other single factor.

There is not the same reason for the disappearance of the once picturesque feature of the landscape in many parts of the coast, the bald eagle. On account of the bad reputation he has or has had —I do not feel at all sure that it is well deserved—a bounty has been placed on its head, and now one seldom sees a single bird on the trees where, such a short time ago, the white heads showed up everywhere.

On the other hand, the various species of gulls, protected and even fed by man, are thriving mightily. It is true that their eggs have been used to some extent in some localities, but this can not have a great or even an appreciable effect on the whole gull fauna.

It may be going too far afield, except to mention it as an example, to refer to the wholesale slaughter of albatrosses and other large sea birds on Laysan Island, some years ago, and the much more recent destruction of birds and birds' nests on that island through the introduction of rabbits.

Of the fishes, the halibut has possibly suffered the most when its whole range is considered. Of large size, slow at reaching maturity as compared with most other fishes and to some extent at least gregarious, it is not standing the strain of the heavy fishing. Bank after bank has been more or less completely fished out, forcing the fishermen farther and farther afield. For the halibut, though, as for the fur seal, apparently the dawn of a better day has arrived. An international halibut commission has arranged for an investigation upon which may be based regulations looking to the conservation and restoration of this great fishery. The problem is much more complex than the fur seal problem, but there is no reason to doubt that it can be solved.

Another large fish, the sturgeon, although it has not come into the commercial prominence the halibut has, is in greater danger of extermination, with at present, no indication of any relief. Possibly it should not be called a marine species, although it reaches tidal waters.

Whenever North Pacific fisheries are considered the salmon question must come up. The individual salmon are not so large or so valuable as the halibut, but the fact that they occur in such great numbers and that they all go up into fresh water to spawn makes them so readily accessible that they provide the most important industry on the coast. The king salmon and the coho suffer persecution continuously, as they will take

bait at all times of the year throughout their whole life. The sockeye, the humpback and the chum never do so and they are thus free from attack while they remain in the open sea. Unfortunately for them, though, they all school extensively as they enter the rivers to go up stream to spawn, thus becoming easy victims to the net. No Pacific fishery has been more subject to regulation than the salmon fishery, but much of the regulation has been of no avail, if it has not been actually harmful, because there was too little information upon which to base it. Such information is gradually accumulating, and with the spirit of international cooperation in conservation that exists to a greater extent than ever before (in fact, until recently it was almost non-existent), there is reason to believe that the salmon may long continue to provide material for the greatest fishery on the coast.

We might go on to speak of herring and pilchard, tuna, albacore, smelt, oolachan, sable fish, gray cod, ling cod, rock cod, flounder, sole, brill, etc., all molested by mankind to a greater or less degree. Some of them have been fished at certain centers much beyond that which the supply could stand, but there is not definite information enough about the life history of any of these to say that this is true for the whole coast.

Of the invertebrates, the exploitation has been confined almost entirely in the North Pacific American waters to the mollusca and crustacea, and these, shore and shallow water forms. Because of this the fishing has been intense in certain centers, so intense as to bring about great depletion, in some cases almost complete extermination, but as to the extent to which this local depletion affects the whole coastal distribution it is not possible to tell from the information available. This must vary much with the species. The oyster, the abalone, various species of clam, including the razor clam, the cockle and the scallop, among the molluscs, to which might be added the squid and the octopus for oriental use, and the crab, the spiny lobster and the shrimps, among the crustacea, are of great enough importance to merit consideration.

Of plants, little can be said under this heading. During the war, certain kelps, mainly *Macrocystis,* were used extensively for the production of potash and then and since, to a slight extent, for such by-products as algin, iodine, etc., but the amount used could have had little lasting effect on the general supply.

Disturbing the Natural Balance by Unequal Drain on Species

As an antithesis to the exploitation of commercially valuable species, there has been a lack of destruction of animals that prey on these. The result of this is twofold. Since the numbers of certain species are so much reduced, while the animals that prey on them are not so reduced, those that remain are hunted more persistently, so that the situation, serious enough, is further aggravated. Even with more zealous hunting by these predatory forms, enough food may not be obtained from the species formerly attacked and attention may or must be turned to other species, thus bringing about unwonted destruction among these. The upsetting of the natural balance may have far-reaching results.

Many parasites are restricted in their distribution to one species as their host. If the individuals of that host species become scarce it must follow that either the individuals that remain must become more extensively infected, laying still further burden on the species, or the parasites themselves must become reduced in number. Hence although man can have little direct control of parasites affecting marine species, he may, indirectly, have much to do with the control of their numbers and their distribution.

Of the larger predatory forms, the

shark tribe, with the ubiquitous dogfish as the most common representative, is most conspicuous. It is true that of late years these have been hunted to be used for fish meal, oil and fertilizer, and in the case of the larger sharks, the skin for leather, but even yet the destruction does not keep pace with that of the common food fishes.

In some respects worse than the dogfish, for it will attack anything in the sea from a whale to a minnow, is the killer or *Orca*. Although in no way comparable to the dogfish in numbers, its size and its extensive field of action to some extent makes up for this. Although it makes inroads in nearly all the species sought by man, from the smallest to the largest, no organized attempt has been made to get any definite idea of the harm it does, or to prevent the continuation of its depredations.

The sea lion and the hair seal might be placed in this category, although, as has already been stated in the case of the sea lion, their effect on the life of the Pacific may not be wholly bad. They have been hunted at times and some satisfactory attempts have been made to utilize the skins. The difficulty in retrieving the bodies has been the chief reason for the general neglect in this regard.

There are many smaller predatory forms, *e.g.*, the sculpins and the lamprey, that must make a great difference in the life of the sea, in the toll they take of the young or the adults of other species, but data on this are almost wholly lacking.

Modifications due to the Changing Conditions in the Sea and along the Shore

Worse than exploitation, because even to man there are no compensating returns, is the destruction of marine forms by changing the physical and chemical conditions of the portion of the sea or shore that has been their habitat. Under this head the main feature is what may be included under the general term, pollution, by which the extent of damage has so greatly increased in the last decade or two. More than in any other way this increase has been due to the introduction of the use of liquid fuels for power boats and for industrial concerns generally.

When crude oil, distillate, gasoline or other similar substances are set free on the surface of the water, a film is formed that may spread over a very wide area, and, particularly in the case of crude oil, when the shore is reached, the whole intertidal area becomes affected. A portion may mix with the sea water or become dissolved in it, and this may be directly poisonous to many of the smaller forms, thus affecting the flora and fauna directly, and since these small plants and animals form the food supply for larger animals, it is likely to affect the welfare and possibly the distribution of these as well. The film on the surface may directly destroy the surface forms by poisoning, but it probably does so more extensively through suffocation, as the film prevents the absorption of oxygen from the air by the surface layers of water.

In a purely mechanical way, in the case of the crude oil again, the wings of birds are clogged and smeared, so that, in many cases, flight is impossible, and since flight is necessary in obtaining food, the birds starve to death.

The intertidal film along the shores has a destructive effect on the plants in the area and hence also the animals that depend on these for food or shelter, as well as directly on the animals themselves.

Beside the destruction caused by liquid fuels and their combustion products, deleterious effects are produced by setting free harmful chemical substances, as by-products of industrial works, sewage and drainage. The effects are similar to those from fuels, although in general they are more local. They are so

numerous, though, that the full effect on the whole coast is very extensive.

Dredging to deepen harbors and waterways destroys the local fauna and flora abruptly. If the dredged material is dumped farther out to sea, as it commonly is, there is a double destruction. The sluicing of land into the sea has a similar effect. Even the deposition of a thin layer of silt may be sufficient to destroy some of the more delicate organisms. A change in salinity, acidity or alkalinity, turbidity or oxygen content may destroy some or drive others away. Even as mechanical a procedure as towing logs may produce detriment, because in shelters where tugs with booms are wont to lie during stormy weather, enough bark sinks to the bottom to make practically a continuous layer, which of necessity disturbs the inhabitants of that area.

Changing Conditions that affect Anadromous Species

Somewhat akin to the changing of conditions that affect species in the sea and along the shore is the changing of conditions that affect anadromous species while they are away from the sea. The effect has been noted more particularly in the various species of Pacific salmon and in the steelhead trout, but is the same in type for all such species.

The main interference with natural conditions is in the placing of obstructions to either the upstream or downstream migration. Until recently the main obstruction to the upstream migration was the log jam, for which man was not always responsible. Of late much more efficient obstructions are being placed in the water courses, dams to retain water for power or irrigation purposes. To make the obstruction less apparent, in some cases "fishways" of various types have been introduced.

These dams serve as an obstacle to downstream migration as well. The taking of water from the rivers and streams for irrigation purposes provides many blind alleys for the migrating fry or young fish. More or less effective screening serves to decrease the mortality from this cause. Pollution produces its deleterious effects here, as it does in the sea and along the shore.

Man, on the Pacific coast, long since realized that these anadromous species could not stand indefinitely the drain on them in sea and river. To offset this drain, and perhaps also to salve his conscience, he tried fertilization, incubation and rearing under control, hoping thereby to reduce the loss in early life.

The Introduction of New Species

Finally a word is necessary on the introduction of new species. We have not been very prone to experiment with the introduction of new marine species on this coast. Is it because we think it difficult to improve the species we have already?

The most conspicuous success in introducing new marine or anadromous species on this coast, or possibly anywhere, is that of the shad. Pretty well fished out in all the eastern areas, where it was indigenous, it has developed so well in its adopted habitat that it provides for a fishery greater possibly than the original fishery ever was.

Perhaps even more extensive but not so conspicuous, because the species is not used for food here to any extent, is the distribution of the soft-shelled clam, *Mya arenaria*, which, since its introduction into the San Francisco bay region from the Atlantic coast, has spread, accidentally or incidentally, until it is now to be found in suitable locations along the entire coast.

Not so successful has been the attempts to establish other species. The Atlantic salmon, the Atlantic oyster, the Japanese oyster, the lobster have all shown indications that satisfactory results might have been obtained if the

attempts to establish them had been a little less haphazard and a little more definitely controlled. Whether it is advisable or not to introduce foreign species is quite another proposition. The more an introduced species thrives, the greater must be the disturbance among the species already there, even if it means only a struggle for food supply. If the introduced species is predaceous, it makes matters so much the worse.

Besides the species that have been introduced intentionally, others, not always desirable, have been brought into the North Pacific area in company with various structures, such as ships, used in transportation, or in structures, such as log booms, themselves transported over the sea. Of these certain marine borers have thrived so well that they have modified conditions directly and as well have modified very materially some of man's modifications.

Summary

To summarize, it may be said that the modifications in the life of the North Pacific, due to man's influence, have, on the whole, not been beneficial to the inhabitants of the sea or of its shores, and in many cases have not been in his own best interests. Many species have been exploited to depletion or extermination for temporarily abundant gain, when by reasonable methods of restraint in conservation a permanent source of supply would provide for less immediate gain, but one much more extensive in the long run.

By the destruction of these species in such numbers, while leaving more predatory species to increase, largely undisturbed, the natural balance has been materially affected.

By polluting the waters and by otherwise changing the conditions of the sea and the shore, areas, once fruitful, have been made desolate and barren.

Even this does not suffice, for the species that escape from the sea and enter the rivers to spawn are obstructed in their inward migration, and they or their offspring in their outward migration as well.

Species from other parts of the world have been introduced. The more lustily they thrive, the greater must be the disturbance among those species that have occupied the habitat that these now take for their own.

There are some indications that man is not wholly callous in regard to these effects. He will still make use of the harvest of the sea. We could not expect it to be, nor could we wish it were, otherwise. He is beginning to realize, though, that a permanent supply from which a fair proportion may be drawn annually is a better proposition than a rapidly decreasing supply that may give out even in his day and that will leave nothing for the future. He is beginning to believe in the necessity for conservation, even if in the most of cases he wishes it to apply to the other fellow rather than himself. He is beginning to see that regulation looking towards conservation, to be satisfactory, must be based on full information concerning the life history of the species under consideration, and at least theoretically, he is willing that support should be given to the investigation necessary to obtain that information. This serves as the basis for national and international cooperation in working out proper bases for conservaiton, which cooperation is already bearing fruit.

Although a balance similar to that which obtained before man interfered will never be, can never be, restored, we may look forward to the time when another balance will be maintained, such that man may take an annual toll from the particular species he may desire without materially decreasing, from year to year, the total supply in the sea—that is to say, that he will take only a number or quantity equal to the natural annual increase.

RADIO TALKS ON SCIENCE[1]

RADIO TRANSMISSION OF MUSIC

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In a lifetime devoted to the study of science, the phenomena of radio broadcasting stand out as the most marvelous of experiences. Personal interest ran through such wonders as the steam-engine, telegraph, telephone, polarization of light, X-rays, radium and wireless telegraphy. Perhaps the most fascinating pastime is to sit before the radio receiver, as in my home in Cleveland, and at will to hear music from one or another of the local stations, or from Pittsburgh or Detroit, or at one's caprice to tune in Boston, Dallas, Denver or even Oakland or Los Angeles at distances of more than two thousand miles.

Wonder is often expressed that we can hear from such great distances, but to me this is not the great marvel. While I am fascinated with the distance-getting, I am awestruck and overwhelmed with amazement when I hear the Symphony Orchestra in New York or St. Louis with such perfection and delicacy of intonation that it seems that I must be in the auditorium with the orchestra.

Who of us can comprehend and fully appreciate the processes by which an orchestra pleases us with its music? Some performers draw a few horse hairs across pieces of animal membrane stretched on boxes, others blow into tubes of metal or wood. Each instrument produces a complex sound wave in air, and the composite of all these waves reaches the ears of the auditors, quietly seated at a distance of one or two hundred feet, who receive sensations of exquisite pleasure (or pain). We can not see the medium or mechanism of transmission in this case any more than we can in radio. We know that the air is the medium of transmission and that it is of such a nature that the sound waves passing through it are quickly "damped" out, and this limits the distance of practical transmission. But space seems to be filled with another medium, which we may be allowed to refer to as "the ether," and which transmits electromagnetic waves a thousand miles more easily than air transmits sound waves a thousand feet.

In the concert hall the extraordinarily complex sound waves fall upon a circular piece of sheet metal, which one might crudely liken to the cover of a tin can; it is technically the diaphragm of the microphone transmitter. In my home the beautiful music of the orchestra is given out by another simple piece of sheet iron, another tin can cover! Certainly, there is much complicated apparatus between the two can covers, but it remains true that all I hear comes from the simple little circular piece of sheet iron. I hear the flute, the trumpet, the quartette of strings, the oboe and bassoon, the drums and bells, and in the complex parts these can be distinguished, each with its characteristic tone-color, when all are sounding at the same time. How can the little piece of tin reproduce the smooth tone of the flute, the strident

[1] Broadcast from Station WCAP, Washington, D. C., under the auspices of the National Research Council and Science Service and the direction of W. E. Tisdale.

tone of the oboe, the majestic pomp of the trombone, and the beautiful harmony of the many stringed instruments, so that one thinks he is listening to a hundred instruments being played by a hundred of the world's greatest artists! This is a thousand times more marvelous than that signals are sent over distances of hundreds of miles.

In the studio of the sending station, the original sound waves fall upon the diaphragm of the microphone. This diaphragm never responds in exactly the right proportion to each and every kind of vocal and instrumental sound wave and combinations of sound waves. The movements of the diaphragm are not accurate representations of the original sound, that is, the wave has suffered a change of form in the instrument, which is called "distortion." The movements of the diaphragm are next transformed into electromagnetic waves, and in this process further distortion is introduced. In fact, every time the wave passes into a new medium or instrument, it suffers more or less distortion.

The electromagnetic waves from the microphone are amplified through an elaborate system of electrical apparatus, that is, they are magnified and lifted up into the ether, and are sent out from the station antenna as powerful electromagnetic waves in the ether. Such waves, after traveling great distances, are very weak, much too feeble to operate a receiving telephone. They can be detected only by means of a complicated receiving set, in which they are amplified; usually there are repeated amplifications. Finally, in the telephone "unit" of the loud-speaker the electromagnetic waves are transformed in the inverse order into actual movements of a diaphragm, impressing the wave-form on the air which passes to the ear of the listener. At every step of this elaborate process there is a lack of perfect response to the impressed force, and distortion is introduced again and again. Much experimenting has been done to prevent distortion and perhaps even more to correct it after it has been produced. Corrections are made by means of condensers, resistances, etc., applied here and there in bewildering confusion. These distortions are heard as a growling background in some voices, or as a shrill sound in other voices; as a predominance of high-pitched sounds in music, producing the effect of a drone which becomes very monotonous. Sometimes the distortion is so great that enunciation is indistinct and spoken words are understood with difficulty. Orchestral music lacks tonal balance and a proper tonal foundation. The crackling noises of static are especially exaggerated and annoy the listener.

Perhaps the least understood and most abused acoustic feature of radio receiving is the so-called "horn" of the loud-speaking telephone. Many inventors and manufacturers seem to think that the material horn itself is the essential thing, but it is not so. The horn is simply a shell that separates a certain quantity of air of a certain shape from the general mass of air filling the room in which the loud-speaker is located; the thing of acoustic importance is the cone of air contained inside the horn. The small end of this cone of air rests on the center of the diaphragm of the receiving telephone and constitutes what, in analytical mechanics, is called a "load" on the diaphragm. The air in the horn is disconnected from the main body of air throughout the length of the horn; it is thus an elastic body capable of its own independent vibration. At the open end of the horn it connects with the air in general. The loud-speaker may be likened to an acoustic broadcasting station, in which the air in the horn is the antenna.

The back-and-forth movements of the diaphragm which are produced by the

electromagnetic devices must, in a loud-speaker, be communicated to the air in the auditorium with a considerable increase in the amount of energy radiated, as compared with a simple ear telephone; that is, the sound must be "amplified." This amplification results from the reaction on the diaphragm of the column of air contained within the horn. With the horn attached, the diaphragm is "loaded" and does more "work" than when unloaded, just as a motor delivers more energy under load than when running light.

Unfortunately, vibrating bodies, such as diaphragms and air columns, have natural periods of vibration; that is, they vibrate more easily at certain frequencies than at others. If a complex set of vibrations is impressed upon the system, it will usually respond in greater degree to those components corresponding to its own natural periods, and these components will be exaggerated; this is called resonance. Sometimes the vibrating system refuses to respond to certain frequencies or to frequencies beyond certain limits; this results in certain component sounds being absorbed or filtered out of the composite. Sometimes the composite vibrations will cause some part of the system to vibrate in its own natural period when there is no component of this frequency present in the original sound. All these effects result in a distorted wave-form.

When the air-column in the horn is made to vibrate in response to the movements of the diaphragm, what are called stationary air waves, with nodes and loops, are formed. It follows naturally that a short horn, enclosing a short column of air, can not respond to sounds of long wave-length. The sounds of speech of a baritone voice contain component waves having a length of ten feet or more, and orchestral music contains sounds having waves twenty feet or more in length. A short horn can never give an adequate reproduction of such sounds.

While it is not possible to secure all the desirable effects and to avoid all the undesirable ones in the design of a horn, yet much better results can be secured than are usually obtained by the loud speakers in common use. It is at once evident that it is not the material of the horn itself that is concerned; it is the column of air inside. It is necessary that the walls of the horn should enclose a column of air of the desired shape, volume and length, and that it should permit of the freest possible vibration; beyond this it should have no effect. In order that the diaphragm may deliver its energy most effectively, the small end of the horn should be small; it should not be too small, else the long slender tube of the throat will introduce friction and obstruct the free vibration of the air column. In order that the energy may be properly distributed over the auditorium, the large end of the horn should be relatively large. Theory indicates an inconveniently large opening, and in practice a compromise, with a smaller opening, is generally adopted.

In the physical laboratory of the Case School of Applied Science, in Cleveland, there has been developed an instrument called the Phonodeik, which makes photographic records of the forms of sound waves; this provides a most excellent means of determining the acoustic efficiency of a loud speaker. A set of eighty standard organ pipes covering the range of the usual musical sounds of frequencies from sixty-four to forty-one hundred is used. Each pipe is sounded separately in front of the Phonodeik and a photographic record is made of what we may call its normal tone. These pipes are then taken to another room, out of hearing. Each pipe is now sounded in front of a regular microphone transmitter such as is used in broadcasting. The electromagnetic waves are conducted by

wire to the loud speaker in front of the Phonodeik, where the pipes were first sounded. The reproduction of each pipe by the loud speaker is again recorded by the Phonodeik. In this way it is possible to compare the results given by different loud speakers and by horns of different designs on any one loud speaker. Such experiments have been made for various types of instruments and for horns of many designs. The records clearly show the resonances, distortions and limitations of the various devices.

These investigations show that the exponential horn, that is, one in which the increase in cross-sectional area is uniform throughout its length, is distinctly better than a conical horn or one of the so-called "morning-glory" type; preferably it should be straight; it should be at least eight feet long. Probably metal is the best material, the inside being smooth and polished and without obstructions of any kind. Many trials with such a horn indicate conclusively that speech is more natural and music very much more musical. The richness and tonal body of orchestral tone-color is reproduced marvelously well. To appreciate these effects one must listen to a loud speaker equipped with such a horn.

There is very little that the amateur or individual user can do to remedy the remaining deficiencies in radio transmission. The conclusions reached from theory and from laboratory experiments are rarely directly applicable in commercial products. But I wish to assure you that there are many eminent and very competent scientific investigators continuously carrying on researches of the most profound kind to discover improvements in radio methods and apparatus, which will be made available by the great manufacturing establishments. Wonderful as is the perfection attained in radio broadcasting, we must remember that it is but an infant in years. I feel confident from personal knowledge of conditions that in the not distant future there will be radio apparatus which is simpler than that now in use and in which the transmitters, detectors, amplifiers and loud speakers will perform with much less distortion. We shall hear speech and music from great distances with such perfection that the hearer would be quite unable to detect any difference between the original speaker and the reproducing loud speaker, or between the symphony orchestra as heard in the listener's home through the radio receiver. When this is accomplished, our thanks will be generously extended to the radio scientists and engineers.

PROPHECY OF A CHEMIST

By Dr. WILLIAM J. HALE
NATIONAL RESEARCH COUNCIL

We live in a chemical world and our daily life is just a little group of chemical reactions under proper coordination. In order to gain a clear insight into the future of this chemical world we are forced to enter upon considerations exclusively chemical and physical. Even here our views may easily be distorted unless we can secure a second position for our observations, namely, that of the open mind. This position in triangulation may be looked upon as one projected into space. In this second position there must be absent from our

minds every trace of those inheritances from a darkened past with its superstition, sentimentality, religious bigotry and political bias. Thus, between these two views we shall surely see ahead, no matter how so little, but surely in proper perspective.

This power of looking ahead with chemico-physical biological interpretation and without mental hindrance of any sort may well be described as a new sense and certainly as ideal scientific vision. Many men of the past have clearly shown in their writings that they possessed no small degree of scientific vision, but their teachings were branded as heretical and heresy was then a thing to be reckoned with. To-day, even the term itself is cloaked in obsolescence.

To many of us who revel in chemical and physical data the happenings of the day are viewed with not much more than flitting fancy, for we realize that they soon must give way to bigger and better things. Let us then call up a few of the present-day pictures and project them into the future in order that possible comparisons may stand out more decidedly in contrast.

The greatest chemical discovery of the past few years is the Patart process of alcohol synthesis from carbon monoxide and hydrogen under higher temperatures and pressures. Speculation is rife on the possible development of this process. From a broad viewpoint, however, the story has scarcely begun. New syntheses involving carbon monoxide, carbon dioxide, hydrogen, ammonia and other gases are soon to introduce a vast array of oxygenated and aminated hydrocarbons of incomparable value. Thus organic chemistry stands at the threshold of a future so vast and with such ramifications as to surpass our wildest dreams. We may safely predict that the greatest developments in the very near future will lie directly in the application of physical chemical principles to the science of organic chemistry.

The study of catalytic processes is receiving constant attention and yielding results of greatest value. Thus, crude petroleum and shale oils will soon be made to yield a very high percentage of low boiling hydrocarbons of unsaturated type. When these are admixed with the alcohols of the Patart process we shall have our new motor fuel. Those who fancy automobile manufacture to have reached almost its saturation point for home consumption little know the future in store for the auto bus alone. Railroads will operate countless busses paralleling their lines as local carriers, leaving to the railways the through passenger and freight traffic. It is not at all unlikely that, for these motor busses, and close to the railroad lines, will be laid a type of rail-bed composed of waste from sugar cane and corn and other grains, together with binding material. Furthermore, steam locomotives will eventually be replaced by the electrified type, but in the meantime a great step in advance over the present, with a saving of 25 per cent. of fuel, may soon be consummated by the installation of the bi-fluid type of engine.

The aeroplane is destined primarily for rapid transit. New types or combinations will make the aeroplane just as safe as a parachute, for it will be immediately convertible into such at a moment's notice. Alloys of magnesium and aluminum will certainly constitute the entire structure of the plane proper and the assured possibility of very high compression in the explosive mixtures for the motor will make for increased efficiency and power. Such development of the aeroplane will arise more economically through commercial enterprise and thus we hope that many aero-transportation companies will soon be in operation.

The use of the aeroplane in possible war is, of course, of primary importance to any self-respecting nation. The old adage, "Be not the first by whom the new is tried, nor yet the last to lay the

old aside," was never more decidedly banal than it is to-day. Possibly there is an old-fashioned kind of pride in beholding one's country's beautiful battleships ploughing gracefully through the mighty deep, but here assuredly is that political bias asserting itself. Such ships are practically useless in battle and worse than useless in self-defense. The chemists have sealed the fate of such and the aeroplane is the means of inflicting the mortal wounds. You read of controversial matters relating to the possibility of blowing up a battleship with aeroplane fire. It makes good reading, but in the wars to come no such harsh treatment will be administered, for the enemy will adopt the newer methods and quietly incapacitate the occupants of these ships in the darkness of night and seize the boats for preservation in their museums, as illustrative of that form of weapon once used in the period of cumbersome warfare.

Naturally, every rational man must ask himself the why and wherefore of building battleships. It is only a sop to the national pride of those who can not throw off sentimentality and immediately grasp the new. Science progresses steadily and can not be stayed. Inside of ten years only the speediest cruisers, aeroplane carriers and submarines will constitute the backbone of the navy, and the aeroplane will be the strongest arm of both the navy and the army. One of the saddest commentaries on America, as a wideawake nation, is that those in authority have not now the courage to follow the advice of scientific men as well as popular opinion and scrap every battleship in our possession and direct that the moneys so saved shall be expended in every form of research that may bear upon the development of aeroplanes and air travel. It is just now coming home to us what Germany has been able to do in the way of discovery and invention when forced by the allied nations to turn her attention from the folly of building and maintaining battleships and to apply herself to industrial research.

With this development of rail and air carriers the biggest factor, the farm, must also claim our consideration. So much is heard of the farming industry and of the depressions it suffers that we begin to wonder why all this furor. Only twenty-five years ago we were a nation of miners, shepherds and grain growers, supplying products to foreign countries where through cheap labor these products could be converted into manufactured goods and as such resold to us under no greatly enhanced price. The farm wastage per acre was insignificant then in comparison with the profits and especially so when the dollar had a greater purchasing value. To-day we have become industrialists. Through a decrease in the purchasing value of the dollar, labor naturally requires higher wages and the price of manufactured goods also soars. The industrialists, therefore, are constantly forced to decrease their manufacturing costs and this decrease strikes first and most severely the dealers in raw material—primarily those particular commodities coming from the land.

Now that the farmers have been drawn into this same industrial whirl they must also readjust their operations accordingly. It is just as necessary for them to avoid overproduction as it is to install proper storage and avoid wastage. The farmers must enforce lower cost of production, steady sales and rapid delivery just as any modern industrial institution, and yet how many of our farmers realize their transformation into industrialists. If there is any blame to be meted out, it must be meted out to the farmer himself. His has been a glorious existence in bygone days—the cradle of America's independent thinker and citizen; the backbone of our democracy. We would not disturb this ideal status.

We would only glorify it the more. Let us then dismiss sentimentality and look upon each other as what we are—parts of an enormous industrial unit where there is no independence or rest until the day we retire.

We read of all sorts of suggestions for the betterment of the farmers and the best of these is the so-called cooperative marketing, commendable in itself and certain to benefit those who participate. But why grasp only one horn of the dilemma when we can take it all bodily and become master of the situation. Cooperative marketing is good; so also is cooperative purchasing. But cooperative farming comprises every activity and when groups of these small industrial units, the farms, are placed under scientific management, then, and not till then, shall we see the metamorphosis of the farm into that of a new and greater power, the home of bliss and content.

Time was when the gross income from a small farm constituted a relatively large return on the investment. This return might still obtain, even on the greatly enhanced value of the land, but the operating expenses have curtailed the possible net income to a point where scarcely more than living expenses remain for the farmers. We can not eliminate competition without wrecking the bulwark of civilization. There remains the direct necessity of curtailing overhead and operating expenses and thus increasing the net income to the farmer. The single farm is entirely too small a unit upon which such curtailment can make an appreciable effect. The operation of farms in groups, however, will admirably serve this purpose. Individualism will still remain, but it will be typified in a group or family rôle and the process may be described as merely a step up from our present-day family of five to one of five hundred. This is the trend of all business and of all industry in general.

It is interesting to watch this modern trend and note, for example, that of the annual crop of three billion bushels of corn already 15 per cent. leaves the farm for manufacture. The day will come when 50 per cent. of it will come into the industries and the by-products will return directly to the farm for the fattening of stock. The oat-hulls and corncobs of to-day are just beginning to come into industrial use. It may seem a far cry to us that we shall raise oats for the oat-hulls and use the by-product, or kernel, in cereal manufacture, but that day is surely coming and coming soon. Main products and by-products are interchangeable terms in the parlance of the industrialist. They are not so with the farming industry, and hence, if we would bring the farming industry into the first rank, we must introduce likewise every new phase of economic efficiency.

Since the dawn of this new industrial era our exports of raw material have shown appreciable decline. To prophesy fully, we ourselves shall be importing grain within ten years and selling enormous quantities of finished goods abroad. This is the natural consequence of efficient manufacture. Simultaneously, there will follow, through keener and keener competition, a lowering in price of finished article to that point where profits can accrue only through mass manufacture. The prosperity of the industries spells likewise prosperity to the farmer, but with the absorption of more and more products from the farm into the home manufacture it becomes evident to all what a cataclysm to the farmers will be registered by any depression in our industrial activity.

Our manufacturing industries are flourishing to-day as never before. Some, of course, will fail where foresight and research are absent, but such should fail by all the laws of science. It is only the most wideawake organizations that can

forge ahead. New processes and all possible combinations are ever emerging and taking effect. Products made for years by old-time processes are meeting with such innovations as would shock their first discoverers. Chemically speaking, our processes are just entering a new régime, a régime first inaugurated by the Haber ammonia synthesis and more recently by the Patart and other processes. The future so far outdistances the present in the scope and breadth of its utilization of every known thing that what calls for your approbation and wonder to-day will serve only as of insignificant historic interest in the days to come.

For these enormous developments that await us, one of the greatest requirements is that of power. Water power will come into greater and greater development, but all the water power in this country can not give us more than fifty million horse-power. We must, therefore, look elsewhere, and here the visualization of the future at greater distance seems most appropriate. The sun's rays are the source of all power to-day, whether it be direct or indirect. The sun's rays, too, will be the source of power in the future and with much of the indirect sources rapidly nearing exhaustion we shall turn to the sun itself and through chemical means involving complicated reactions bring this energy under control. The economical photosyntheses now being studied are of more or less complicated nature, but it is safe to say that they require not only a high degree of sunlight but contiguity to large bodies of water—such ideal conditions as may be found on islands in the southern waters between here and South America.

We read in the papers of the foreign financial obligations to this country. Many are the pages and lengthy is the treatment given, but never has been heard an open scientific discussion of the problem. Political bias decrees that such matters be left to our posterity where the rôle of necessity may, if it will, enforce itself. Preparedness is a harsh mistress, and not many can cope with her. If only our public men could cast off all sentimentality and diplomatic deference and enter into these dealings upon a strictly chemical basis, what a grand opportunity to help both ourselves and our friends across the sea! A number of the possessions of France and England in the southern seas will undoubtedly come into value for us within twenty years. To-day they have no value for us and but little for either France or England, but when we shall have to purchase these possessions, as will surely come to pass, we shall be only too glad to pay a sum equal to, if not in excess of, the entire foreign indebtedness to us. Why not make the deal now and wipe out foreign obligations, thus stabilizing both financial and economic relations between Europe and America? In the past others high in public life have acted in a similar manner and wisely. Who to-day would question the wisdom of the purchase of Alaska? The course of progress indicates that southern countries must come into development for many of the new industrial activities, and by acquisition of certain of these possessions that can come into present-day consideration we are only building for our successors.

Many may question why chemists, physicists and biologists are particularly endowed with a sort of ultra vision. Since the early days of alchemy it appears that this has been a trait of those skilled in the manual arts. One need not qualify as an expert in any of these sciences, but he must be schooled in chemical, physical and biological laws if he would be able to weigh accurately the events of everyday life, for are not all these events just the results of life processes—which in turn are governed by

these laws? From such scientific viewpoints triangulated with one far distant from human frailties what a wonderful picture our observers may behold of the mighty and magnificent future that awaits us and our posterity.

THE FIXED NITROGEN RESEARCH LABORATORY

By Dr. S. C. LIND

ASSOCIATE DIRECTOR, FIXED NITROGEN RESEARCH LABORATORY

MANY of the radio hearers may not know that since the close of the late war, the government has maintained in Washington, on the campus of the American University, a laboratory devoted to the fixation of nitrogen. You will naturally wonder what is the importance of this one element that a laboratory with a staff of seventy-five or eighty men should be employed in the problem of capturing nitrogen from the air and of causing it to combine chemically with some other element which we call "fixing" it. You may imagine that the problem of fixing nitrogen is both difficult and important and that it has a new significance that arose from the war, all of which is true.

Nitrogen in some respects is one of the most baffling of our chemical elements. Its atom is the seventh lightest of all the elements, being preceded only by hydrogen, helium, lithium, berylium, boron and carbon. Its atomic number *seven* being odd indicates according to Harkins's rule that it should not be a very abundant element, and yet it constitutes four fifths of the volume of the atmosphere. This apparent exception to the rule is due to the fact that nitrogen does not form compounds of sufficient stability to exist in the earth's interior and therefore nearly all of it is concentrated in its free state in air. However, nitrogen does not constitute a large fraction of the earth's total mass, although abundant everywhere on the earth's surface.

The sluggishness of nitrogen in entering into compounds early gave an exaggerated idea of its chemical inertness. The French named it "azote," a word of Greek origin meaning "without life." Yet it is a very active and essential component of all plants and animals; it is therefore absolutely necessary in some form as a plant food. Since its inertness in the free state prevents it from being directly assimilated, it must first reach the plant through the soil in some combined or fixed form.

The nitrogenous matter normally present in all soils becomes depleted when the natural processes of the return of nitrogen are unbalanced by crop removal. This exhaustion of the soil entails the problem of artificially fixing nitrogen of the air so that it can be resupplied to the soil in some form of fertilizer.

Another great use of nitrogen compounds is in industrial and military explosives like nitro-glycerine, tri-nitrotoluol, gun cotton, dynamite, etc., all of which require nitric acid, an oxidized derivative of nitrogen.

The principal sources of nitrogen compounds, besides those in the soil, are coal and Chile niter. A vast total quantity of nitrogen is stored in coal and may be obtained in the form of ammonia when coal is distilled to make coke or coal gas,

but the nitrogen content of coal is low, one half to two per cent., and of this only about five pounds of nitrogen per ton of coal are recovered in coking, so that it is not profitable to mine and distil coal for nitrogen alone. The coke and gas industries can not supply more than half of our nitrogen needs. Chile niter, or nitrate of soda, a natural salt occurring in Chile, has until recently supplied most of the balance, but it is a highly localized source of supply, not dependable in time of war, due to difficulties in its production, export and transportation.

The only remaining alternative is the nitrogen of the air. This source is tremendously large compared with the others, ten to one hundred thousand times the total tonnage in coal and Chile niter combined, and yet prior to 1905 this vast and universally available storehouse had never been tapped except through certain processes of nature which we have not yet learned to imitate. It recalls the familiar story of "water, water everywhere, but not a drop to drink." We are surrounded by nitrogen, it constitutes three fourths of the fourteen pounds of weight pressing on each square inch of our bodies and four fifths of the volume of air we breathe. We inhale and exhale a weight equal to that of our entire bodies every five days, but, as far as we know, the lungs fix no nitrogen and it leaves us again a complete stranger. Without artificial fixation processes the human race, though living at the bottom of a sea of free nitrogen, would sometime be faced with the danger of nitrogen starvation.

Just before the war Germany solved the problem of cheap nitrogen fixation. In fact, a close connection has been alleged between this discovery and the beginning of the war, for it at once made Germany independent of Chile niter for war explosives and insured nitrogen fertilizers for her soil. Just before and during the first year of the war the tonnage of fixed nitrogen in Germany reached two hundred thousand tons per annum, or nearly equal to our present total use of it in fertilizers. At the close of the war the German tonnage had risen to three hundred thousand tons per annum, and has since been increased to four hundred and twenty thousand tons, or nearly twice our consumption.

Nitrogen fixation is now being studied and applied throughout the civilized world. It has become a form of international competition which we can not ignore if we would. The United States on entering the war established two plants at Muscle Shoals, one designed for five thousand tons per annum, to operate under a modified German process, and the other for forty thousand tons, to operate a method which had been successful at Niagara Falls, but which was tending toward obsolescence through the introduction of the newer process. Two things were clearly shown by the experience obtained up to the time of the armistice; first, that we were not sufficiently acquainted with the German process to operate Plant No. 1 at Muscle Shoals successfully, and second, that the larger or cyanamide plant might in peace-time become a perplexing problem through not being directly adaptable to peace-time needs. Operation of both plants was deferred and no further disposition has been made of them as yet.

In 1919, the War Department decided to devote part of the nitrogen fixation funds to a fundamental study of different processes, and accordingly established the Fixed Nitrogen Research Laboratory in Washington. In 1921, the laboratory was transferred to the Department of Agriculture, as it was evident that the peace-time use of fixed nitrogen in fertilizer represented the dominant need.

The laboratory was endowed with sev-

eral different functions—one to become acquainted with all the methods of nitrogen fixation, and to make this information available to our government and to the industries. Second, to provide by observation and experiment a basis of decision as to what processes are best adapted to American conditions.

Prior to the development of the German or Haber process, there had been two principal processes in use, each having its own peculiar advantages.

The arc process, which had its earliest development at Niagara Falls, first became commercially successful in Norway. It consists in passing air through the electric arc, which, in virtue of its extremely high temperature, causes a small part of the nitrogen and oxygen of the air to unite directly to form oxides of nitrogen that can readily be converted into nitric acid and nitrates, useful both as fertilizers and explosives. Owing to its excessively great consumption of electric power the arc process has not been generally applied outside of Norway, where huge quantities of hydro-electric power are to be had cheaply. Although there is no immediate hope of the revival of the arc process in the United States, the direct union of the nitrogen and oxygen of the air in some economical way is so desirable and has such patent advantages that it will some day be accomplished, and until then it must remain one of the outstanding problems of the Fixed Nitrogen Research Laboratory.

The cyanamide process had also been developed at Niagara Falls and was put on a successful commercial basis as early as 1908. It was therefore possible for the government to secure the cooperation of an American company to install its process at Plant No. 2 at Muscle Shoals. This process also involves the use of rather high electrical power, although much less than does the arc process. The product, cyanamide, may be converted to other nitrogen products or be used in mixed fertilizer to correct soil acidity. The latter use is a definitely limited one in this country, and it is still an unsolved problem to provide additional outlets for cyanamide products, either as fertilizer or in other ways.

The third and now most important process is the German, or Haber, process, involving the fixing of nitrogen by union with gaseous hydrogen to form ammonia, the salts of which can be used as fertilizer, or which can be oxidized to form nitric oxide, the same as the primary product of the arc process. The great tonnage of synthetic ammonia now being produced in Germany has, in spite of the early difficulties encountered in Plant No. 1 at Muscle Shoals, stimulated great interest in this country and kept up the hope that the process, already installed on a small scale by a few companies, will soon be expanded to a tonnage that will make itself felt in lowering the cost of fertilizer nitrogen. The Nitrogen Research Laboratory has, therefore, put its utmost efforts into mastering the intricacies of this method, so imperfectly understood in this country at the close of the war. The heart of the process consists in passing the gases, nitrogen and hydrogen, at very high pressures and fairly high temperatures (dull to bright red glow) over a substance called the catalyst, the function of which is to speed the rate of combination which would otherwise be too slow for commercial purposes. The catalyst body developed by the Fixed Nitrogen Research Laboratory has given good results under commercial conditions, and is now at least equal to that used in any other country. It consists of iron reduced from its fused magnetic oxide and contains about three per cent. of alumina and one per cent. of potash. The laboratory has worked out the mechanical and engineering details so as to operate at a considerably higher pressure than the German process, and has de-

vised many new engineering features of high pressure technique.

At present the United States occupies but tenth place among the nations of the world with respect to the fixation of nitrogen, and this despite the fact that we are the second consumer of total nitrogen. One small arc plant is in operation on the Pacific Coast. No cyanamide plant, except the idle one at Muscle Shoals, exists in the United States, but an American company is producing on the Canadian side of Niagara Falls. About a half dozen synthetic ammonia plants are now operating and others are soon to begin, which will give a total capacity of about ninety tons per day, but no single one will exceed a daily capacity of twenty-five to thirty tons. This is but a small beginning compared to Germany's daily production of fourteen hundred tons. But our position is quite different. Germany's installation was a war subsidy, which is now being operated to amortize the investment in these plants and to avoid having to import nitrogen. The European countries have much smaller steel and coke industries and hence less by-product ammonia, and are also remote from Chile niter, so they are more directly forced to develop their air fixation processes than we are. Necessity being the mother of invention, the German process was devised to meet a unique situation and is now not only being profitably operated but actually expanded at a rate exceeding new installation in any other country. Looking to our agricultural future, as our virgin soils become more depleted, we shall have to use more nitrogen fertilizer per acre, as in Europe, consequently we must augment our nitrogen fixation.

All indications point to a great expansion of this industry in the next few years. Catalytic processes under high pressures, which have now attained one thousand atmospheres, represent a radical innovation. Advances are certain to be rapid; and a vigorous research program is essential to insure the position of the United States in this branch of world industry. The strength of our position lies in the fact that we now have a knowledge of its technique, while we need not be stampeded into improvident or uneconomic developments.

Perhaps such concerted effort has never before been focused by all the civilized nations on the chemical technology of a single element. The Fixed Nitrogen Research Laboratory has formed a center in this country for collecting and obtaining information and engineering data necessary for the development of the nitrogen industry. Recently, in passing through the machine shops of the laboratory my attention was arrested by a striking operation. The barrel of a large naval gun was being bored out, to convert it into the catalyst chamber of a high pressure ammonia converter. This, as it struck me, is a twentieth century version of beating the sword into the plowshare. The transfer of the Fixed Nitrogen Research Laboratory from the War Department to the Department of Agriculture was but a larger expression of the same desire to turn one of the many liabilities of war into an asset of peace.

RELATIVITY AND LIFE

By "BETA"

I HAVE been criticized for attempting to write anything about relativity inasmuch as I am not a mathematician, but it seems to me that this criticism means that my critic thinks there is only one frame of reference from which relativity can be measured, namely, mathematics. But this is a denial of the fundamental thought in relativity. The germ of relativity consists in the idea that there is no one frame of reference from which alone reality can be measured. Does not this idea apply to relativity itself? Can not a man measure relativity from a non-mathematical frame of reference? This is what I am attempting in this paper.

I wish first to define the term absolutism. By absolutism I mean the theory that states there is one unique frame of reference from which alone reality can be correctly measured. Now relativity is not so much a new affirmation as a denial of the old affirmation absolutism. In the history of ideas there have been three great movements from absolutism to relativity. The first was in religion. The church claimed there was only one frame of reference from which to measure spiritual values, namely, the Old Testament as interpreted by the church. Luther introduced relativity or the right of private judgment. The next was absolutism in government or the divine right of kings. Democracy set up relativity or government by changing public opinion. The last stronghold of absolutism was in physical science, where it was long held that there must be one frame of reference from which alone length, mass and time can be correctly measured. Michelson tried to prove this with his measurements of the velocity of light and failed, and then came Einstein, who destroyed the last absolutism as Luther had destroyed the first.

Now it is the persistence of absolutism in life that causes most of our troubles. Is not the cause of social friction in this world due to the fact that most of us, consciously or unconsciously, are absolutists and will not look at things from any but our own frame of reference? The chaos in middle Europe is due to absolutism in the form of nationalism. I agree that nationalism is a very good frame of reference from which to measure some things. There are several very beautiful things in life which are well worth while and which nationalism sustains, such as art, literature, music, traditions and sentiments. But the trouble is that when we are absolutists we measure everything from one frame of reference. Now if there is anything certain in this world it is that political economy can not be measured correctly from a nationalistic frame of reference. Yet that is just what the people of middle Europe are trying to do and naturally they are making a mess of things. The trouble is that in spite of Luther, democracy and Einstein, the mass of mankind do not yet see that relativity and not absolutism states the truth about life.

Yet there have been men who for thousands of years have been relativists. I refer to artists. You will never hear artists claim there is only one way of expressing the beauty of life. The painter sees beauty in the statue and in

music, in prose and in poetry, in different forms of architecture; he admits they are all different ways of expressing the beautiful. But before Einstein, if a physicist had said that this thing called measured length is not an absolute but will vary according to the way you look at it (which, of course, is just what all artists say of art in general) what would have happened to this pre-Einstein physicist? It is an interesting fact that there has never been the slightest antagonism between art and religion, which is simply because artists are relativists, whereas the antagonism between science and religion was due to the fact that pre-Einstein physicists were absolutists, just like the theologians, and whenever there is absolutism there are always reasons for fighting. Einstein has left the absolutists in physics no ground to stand on. Yet absolutism will be a long time dying out, and I find absolutism as a philosophy existing (often unconsciously) in men who claim to understand relativity. The reason why Einstein overthrew absolutism is because he is not a scientist. Einstein is an artist whose medium of expression happens to be mathematical physics instead of line, color or marble. One has only to look at his picture to recognize the artist.

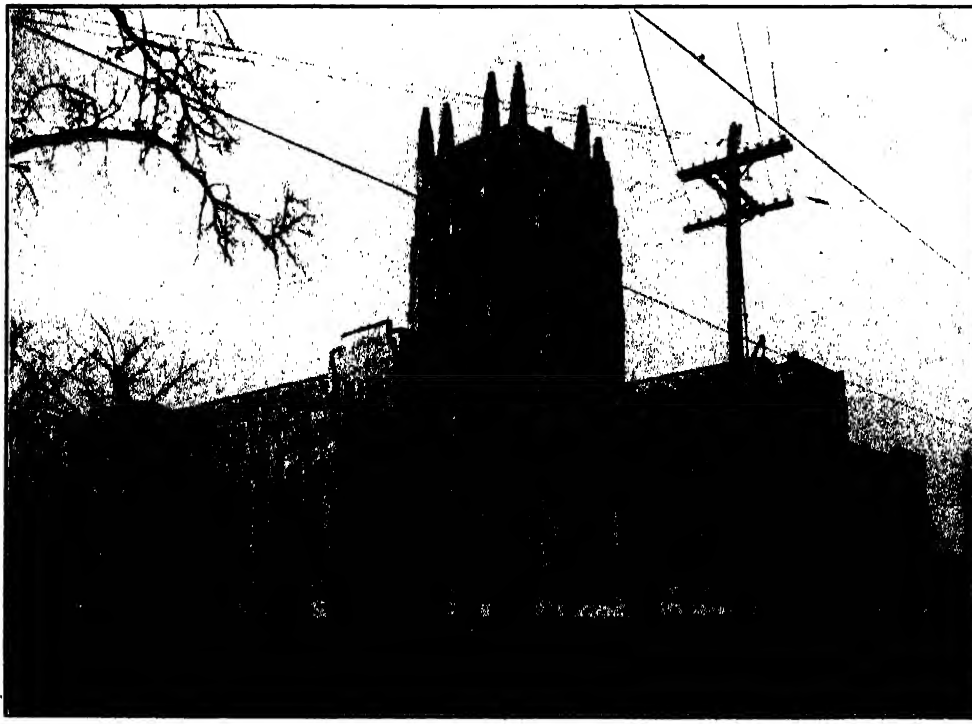
I wish now to make the following heretical suggestions. It seems to me that the difference between the living organism and the so-called non-living is not so much a difference in the "thing in itself" as it is in the frames of reference we use by which to measure it. Mechanism, which we think characterizes the non-living, implies repetition and hence predictability. But Einstein has shown there is no such thing as repetition in any real sense. We get repetition simply by choosing a frame of reference which will show it. Thus, a seconds pendulum repeats if the origin of our frame of reference is the point of support of the pendulum. But if our origin is in the sun, the pendulum will not repeat for at least a year. We can choose a frame with its origin such that we can never prove that the bob comes back to its original position. What then becomes of repetition and the so-called regularity of nature's laws? It does not exist in any absolute sense because we can not find a frame of reference at rest to prove regularity. We get regularity simply by agreeing to ignore the irregularities, and we do this by choosing the proper frame of reference. All that science has the right to say about nature is that it is generosity raised to the nth power. Nature will show us anything we want to see, provided we hunt with the proper frame of reference. The frame we choose is a function of the particular activity which interests us. Whenever we measure a phenomenon in science, our frame of reference must be outside the thing measured. This is the objective method of science, and a constant characteristic of this method is to ignore what does not interest us. So far as science is concerned, it continually measures parts, not wholes.

Now it happens that, being living beings, we have the power of measuring one whole, and that is our own psychical life, and what do we find here? We find creation going on all the time. We never find repetition in our psychical life so long as we view ourself as a whole. This is all that we mean when we say that we grow older day by day. Our second experience is always different from our first experience if only because it has in it the memory of our first experience. This must be true since otherwise how could we know the experience is a second experience? This of itself is convincing evidence of creation and a denial of repetition in our psychical life considered as a whole. But when we cut

ourself up into parts (a very different frame of reference) and examine the parts objectively, of course we find repetition, and hence, mechanism. Each living organism is a closed system to itself, and hence it must be compared only to a complete universe closed in the Einstein sense, in which there is always creation when measured as a whole, but which, of course, shows repetition when measured by parts, that is, objectively.

We have no direct conscious evidence of anything outside ourself, being as we are systems which are closed psychically. To this extent, Berkeley is right. Our consciousness does, however, give us good grounds for inferring the existence of other systems and it is this justifiable inference which has built up objective science. In the same way we may infer the existence of universes other than our own, but, if Einstein is right, we can have no direct knowledge of them. According to Einstein, try as hard as we may physically, nothing can get out of our own universe. Just so, according to Berkeley, try as hard as we may psychically, we never can get out of our own consciousness.

THE PROGRESS OF SCIENCE

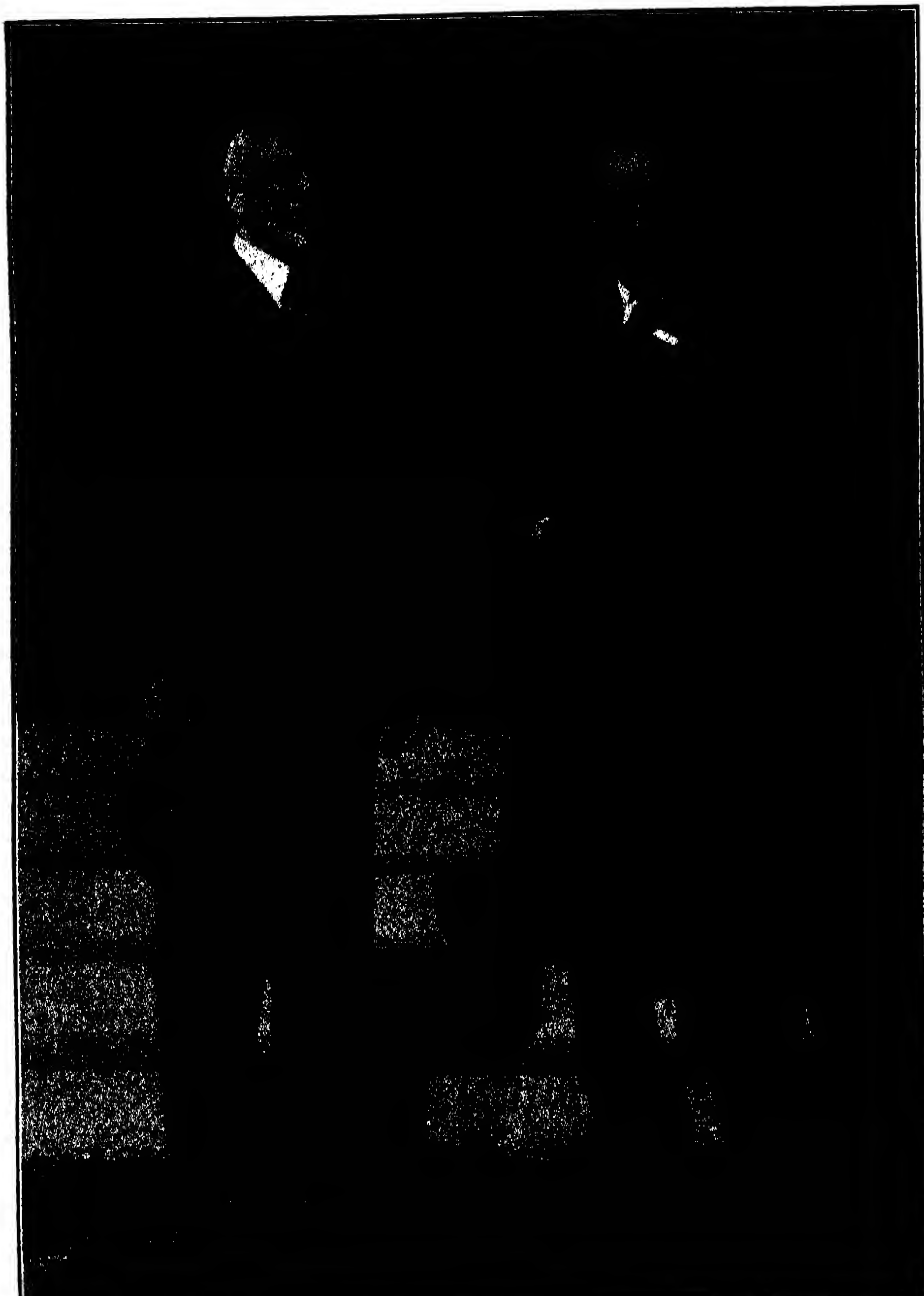


DEDICATION OF THE PEABODY MUSEUM OF NATURAL HISTORY OF YALE UNIVERSITY

AN efficient educational museum, thought Professor G. Brown Goode, "should be a collection of instructive labels, each illustrated by a well-chosen specimen," and circumstances have favored the application of that principle in Yale's fine new Peabody Museum.

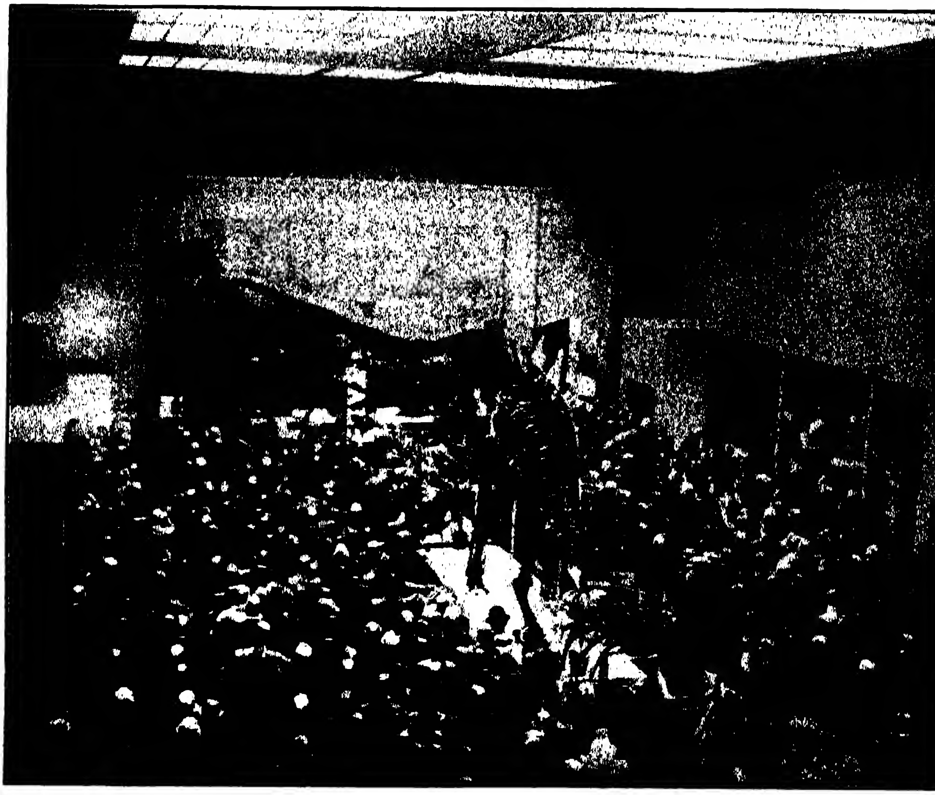
Its old building came down in 1917 to add room for the Memorial Quadrangle. Its collections went into storage. Then America entered the war, and prolonged upheaval followed. Before the exhibits could be reinstalled in a new building, the anti-evolutionary crusade set in, to culminate at Dayton. Thus, when it became possible to resume activity, the museum had not only a new opportunity but a new responsibility—the responsibility, that is, of presenting evolution as a law instead of merely as a hypothesis. This, naturally, could best be accomplished by "a collection of instructive labels, each illustrated by a well-chosen specimen."

In his address at the dedication ceremonies on the 29th of last December, Professor Henry Fairfield Osborn, of Columbia University, quoted Baldwin's definition, "LAW: Any formulation of sequences which from demonstration, experimental proof, successful application, or for any other reason, are accepted as having a high degree of probability." All around Professor Osborn, as he spoke, were exhibits in which labels



DR. RICHARD S. LULL AND PROFESSOR HENRY FAIRFIELD OSBORN

DR. LULL, DIRECTOR OF THE PEABODY MUSEUM OF NATURAL HISTORY, STANDS ON THE LEFT. DR. OSBORN, PRESIDENT OF THE AMERICAN MUSEUM OF NATURAL HISTORY AND RESEARCH PROFESSOR OF ZOOLOGY AT COLUMBIA UNIVERSITY, STANDS ON THE RIGHT.



DEDICATION EXERCISES

THE AUDIENCE SEATED IN THE MAIN HALL OF THE PEABODY MUSEUM. FIVE HUNDRED SCIENTISTS ATTENDED THE CEREMONIES WHICH TOOK PLACE ON DECEMBER 29.

told the story of evolution and specimens substantiated it.

For the first time in America, scientists have the satisfaction of seeing the complete continuity of life illustrated by fragments of concrete reality, and a repetition of the Dayton uprising will hereafter be somewhat difficult. For this is not alone a museum for specialists in research, for scientists in the making, and for undergraduates in Yale College, but at the same time a museum for Yale divinity students, for the people of New Haven, and for children, with a special docent to guide the children through. Inasmuch as Yale has long been a pacemaker in education, it is more than likely that other university museums will soon begin to copy this one. Evolution will be popularized. Meanwhile, the exhibits at Yale are being photographed. The next agitator to stir up a fuss over evolution will find the photographs reproduced in the newspapers, and there the general public will see demonstrations of heredity, of variation, of adaptation and of the evolution of this or that familiar species—the camel, the elephant, the horse, and man himself. Also, some editors may venture to print photographs of evidences from embryology, for those, too, are there.

Evolution dominates the museum's entire lower floor, which is so planned that the visitor begins at the beginning and follows the argument through to its con-

clusion. According to certain remarks overheard at Dayton, he will then be a complete and finished atheist. As a matter of actual fact, however, there are no atheists among the museum's curators, and Director Richard S. Lull is a devout Episcopalian. In the course of his address at the dedication ceremonies, Dr. Charles Schuchert read Harvey Maitland Watts's religious poem, beginning:

> "Great God of nature, let these halls
> The hidden things of earth make plain;
> Let knowledge trumpet forth her calls,
> And wisdom speak, but not in vain."

Just how popular such a museum as this will be is of course a question, but every care has been taken to make it popular. Instead of confusing the visitor by confronting him with crowded cases, only significant specimens are shown—barely a tenth of what the museum possesses. The rest are stowed away down cellar, where the seismograph is installed in a region piled high with packing boxes, or they are arranged in drawers upstairs for use by research workers from all over the world.

Many of the exhibits have an inherent popular appeal — Marsh's dinosaurs, pterodactyls and toothed birds, for example, and the frequent "habitat cases," one of which gives a glimpse of a coal-age forest, while another shows a section of a coral reef with the corals painted in the colors of living polyps, and still another presents models of extinct marine monsters in what might almost be mistaken for real water.

As popular, manifestly, are Professor Lull's novel restorations of extinct animals. He explains them thus: "In the old days, when we had a fossil skeleton that was rather imperfect, we mounted it on a slab. I came to the conclusion that this was waste. Now what I do is to take the skeleton and mount it, and then model flesh on the poorer side of it, working from comparative anatomy of domestic animals, building up the flesh synthetically, and in that way work over the skin done in plastelline.

"After that, we generally leave it for a while for criticism, getting other scientists to tell us what they dislike in it, and proceed to manipulate it until we have attained what we want.

"Then the plaster mould is made. The bones are carefully cleaned and put in place, with irons run through the legs, etc., and plaster of paris is poured in.

"Instead of having only bones, we now have positive or flesh restoration on one side and bones on the other. On the restoration side, we at first used the color of the matrix in which the bones were found. Later, we decided that, as there were certain definite laws of coloration, it was fairly safe to paint according to what we thought the color was in life.

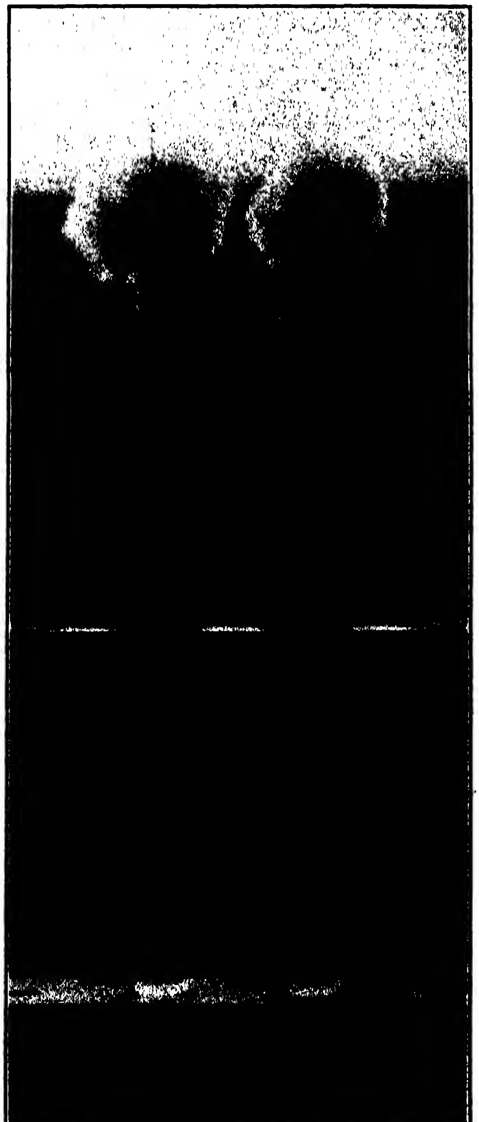
"Then we went still further, and instead of having one animal, assembled a group. From one side, you get a series of ghostly skeletons. On the other side, you see our interpretation of them—what the scientist has in mind."

A striking group shows a giant saber-toothed cat fiercely menacing a prehistoric wolf, and if the cat was not as tawny as the professor makes out or the wolf as silvery gray, it is difficult to prove it.

Upstairs, where the museum's famous meteorites, its superb cabinet of minerals, its ethnological exhibits and its collection of New England animals and birds are installed, evolution is not the theme illustrated. Will these upper halls be more popular on that account, or less so? It is difficult to judge. Just now they seem as popular as those on the ground floor, and if the stories connected with the Marsh collection are entertaining, so are the stories connected with the exhibits upstairs. One such story, retold on dedication day, immortalizes Thomas Jefferson's comment when he heard that two Yale professors had recovered fragments of a meteor at Weston, Conn. "It is easier to believe that two Yale professors will lie," he said, "than that stones fall from heaven."

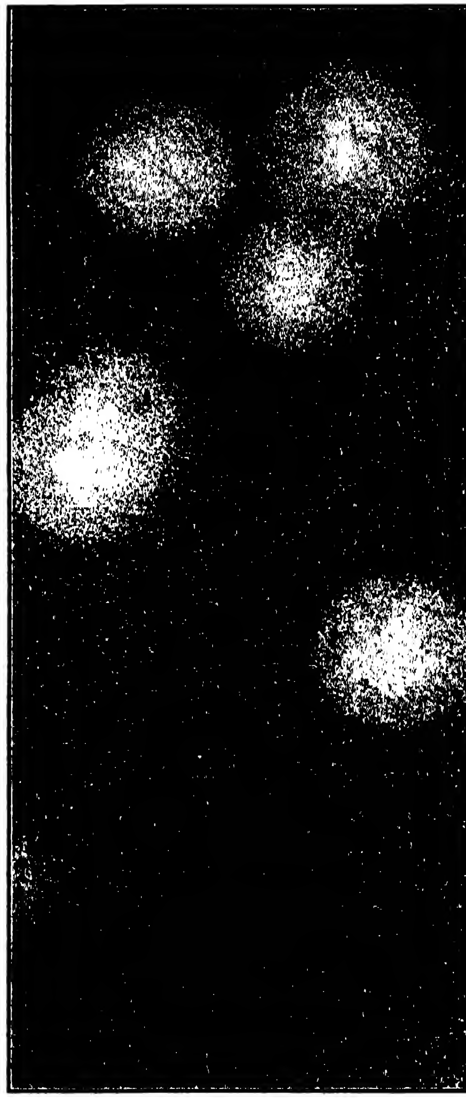
ON THE NATURE OF BACTERIOPHAGE

AN article in the current issue of THE SCIENTIFIC MONTHLY entitled "Do Bacteria have Disease?" assumes bacterio-



AGAR PLATE

ON THE RIGHT IS A CONTROL TUBE OF BROTH CLOUDED BY A DENSE CULTURE OF BACTERIA. ON THE LEFT IS A SIMILAR TUBE 18 HOURS AFTER THE ADDITION OF ONE PART IN 1,000,000 OF BACTERIOPHAGE.



TEST TUBES

SURFACE OF AGAR PLATE COVERED WITH A DENSE GROWTH OF BACTERIA. THE CLEAR CIRCULAR AREAS ARE VOID OF BACTERIA DUE TO THE ACTION OF THE BACTERIOPHAGE.

phage to be endowed with life. This account presents d'Herelle's viewpoint and accepts the theory that it is a minute organism or an ultramicrobe. Do the facts warrant such an assumption? Not nec-

PROFESSOR ALBERT EINSTEIN

THE PHOTOGRAPH (COPYRIGHTED BY UNDERWOOD AND UNDERWOOD) WAS TAKEN AT THE TIME OF PROFESSOR EINSTEIN'S VISIT TO THE UNITED STATES IN 1921.

essarily: A large volume of experimental evidence, collected by various investigators, both here and abroad, suggests that the phenomena described by d'Herelle can be explained without the assumption of the existence of a living ultramicrobe.

According to these findings, the active principle responsible for the dissociation of bacteria may very well be a chemical substance which is a product of bacterial metabolism. While much of the evidence against d'Herelle's hypothesis is too involved and technical to be presented here, the following facts, if correct, have shown that the so-called bacteriophage possesses properties incompatible with life: (1) Bacteriophage does not respire; (2) it is not destroyed by repeated freezing and thawing; (3) it dces not reduce methylene blue; (4) it is not destroyed by acetone or by 95 per cent. alcohol.

Whether the use of bacteriophage in the treatment of disease is destined to revolutionize medicine of the future, as claimed by d'Herelle, it seems important to determine its intimate nature.

THE AWARD OF THE COPLEY MEDAL TO PROFESSOR EINSTEIN

The Royal Society awarded the Copley Medal to Professor Albert Einstein, of the Kaiser Wilhelm Institute, at its anniversary meeting on November 30. At the time of the award the following citation was made:

The name of Einstein is known to every one through the theory of relativity which he originated in 1905 and extended by a notable generalization in 1915. Einstein realized that the time and space with which we are so directly acquainted by experience can be no other than the fictitious *local* time and space of the moving system—the motion in this case being that of the earth; we have no means of determining, nor can physical science be concerned with, any absolute reckoning of space and time. After this Einstein was led to the identification of mass with energy—another result of far-reaching importance which allows us to know the exact amount of the store of energy so tantalizingly hidden within the atom.

There was a feeling that this theory of relativity for uniform motion must be a particular case of something more general; but observational knowledge seemed to oppose a decisive negative to any extension. It was Einstein again who found the way to the generalization by bringing gravitation into his scheme.

Einstein's general theory of relativity is remarkable alike for the brilliance of conception and the mastery of the mathematical implement required to develop it. The new law of gravitation must be reckoned the first fundamental advance in the subject since the time of Newton. It involves an interaction between gravitation and light, which had indeed been suspected by Newton and almost taken for granted by Laplace, though it dropped out of scientific speculation when the corpuscular theory of light gave way to the undulatory theory. The three crucial astronomical tests of Einstein's theory have all been verified—the motion of perihelion of Mercury, the deflection of light, and the red-shift of the spectral lines. The last-named proved the most difficult to test, but there is now general agreement that it is present in the solar spectrum. More recently Einstein's theory of gravitation has appealed to astronomers not merely as something which they are asked to test, but as a direct aid to the advancement of astronomical research. Invoked to decide the truth of a suspicion of transcendently high density in the "white dwarf" stars,

DR. FREDERICK G. COTTRELL

it has decided that in the companion of Sirius matter is compressed to the almost incredible density of a ton to the cubic inch.

The other direction in which modern physical theory has broken away altogether from the ideas of the nineteenth century is in the quantum theory. Probably no one would claim that he really understands the quantum theory. For such illumination as we do possess we are in great measure indebted to Professor Einstein. In 1905, almost at the same time as he published his first work on relativity, he put forward the famous law of the photo-electric effect, according to which the energy of a single quantum is employed in separating an electron from an atom and endowing it with kinetic energy. This was, perhaps, the first recognition that the development of the new quantum mechanics was not to be tied to classical mechanics by pictures of quasi-mechanical oscillators or other intermediate conceptions, but was to proceed independently on radically different principles. Noteworthy contributions followed on the theory of ionization of material, and on the problem of the specific heats of solids. In 1917 Einstein reached another fundamental result—namely, the general equation connecting absorption and emission coefficients of all kinds. This gives deep insight into the origin of Planck's law of radiation, besides providing new formulae with the widest practical applications.

DR. COTTRELL AND THE RESEARCH CORPORATION

THE Mining and Metallurgical Society of America has awarded its Gold Medal for the year 1924 to Dr. Frederick Gardner Cottrell for "Distinguished service in the development of a method of electrical precipitation of solid and liquid particles from smelter smoke, and in recognition of his public spirit in making a gift of the proceeds of his invention for the support of scientific research."

Electrical precipitation consists of the removal of suspended particles from gases by the aid of electrical discharges. The gas containing the impurities is passed between highly charged electrodes. The particles become electrically charged and are driven to one side by the forces of the electric field.

These processes have now been applied in over eighty-four different industries. The recovered dust or fumes from smelter smoke in many cases is valuable and constitutes a large financial saving. In many other industrial operations where noxious gases, fumes or dusts are given off, the process has been successfully applied, some of the materials precipitated being sulphuric, nitric and hydrochloric acids; arsenic, tar, lead, zinc and other poisonous materials.

The Research Corporation was organized at the instigation of Dr. Cottrell in 1912 when he desired to give his patents for electrical precipitation to the Smithsonian Institution. He hoped that if these patents became valuable, the income from their use would provide revenue to encourage other discoveries. The institution, as Dr. Cottrell soon discovered, was unable to transact business because of charter restrictions, and this led to the organization of the Research Corporation in New York under the cooperation of the Smithsonian establishment. Under the corporation's charter no dividends may be paid on its stock nor may its directors receive fees for serving on the board. It is now fulfilling the purpose for which it was founded and it remains in close association with the Smithsonian Institution.

Subscribers to the capital stock have now been repaid and the stock is held in the treasury of the corporation so that

PROFESSOR JOHN J. ABEL

there are no individual stockholders. The assets have been increased until they now exceed $150,000. The annual business is over $400,000 a year, and the corporation is able out of the returns it receives to defray the operating expenses and to make small grants to the Smithsonian Institution and other worthy causes.

This unique institution is governed by a distinguished board of directors and it has for its president Dr. A. A. Hamerschlag, former president of the Carnegie Institute of Technology at Pittsburgh.

The purpose of the corporation is to lend its aid to the utilization of any invention or discovery which offers sufficient promise of promoting the application of scientific discovery to the industrial arts. This it does by acting as the intermediary between the inventor and the manufacturer, subjecting discoveries and inventions to practical tests and rendering a judicial opinion which can be accepted as trustworthy by manufacturers, bankers and others; by safeguarding the rights of inventors during the preliminary period which determines the commercial success or the adequacy of the organization exploiting the products made under the patents and for this service accepting participation in the royalties and license fees; by receiving special funds, by gift or otherwise, to aid talented inventors in the solution of important industrial and scientific problems; by qualifying as trustees for governmental or institutional control of patents so that private enterprise and capital may secure licenses and exploit new inventions.

The Research Corporation, combining as it does technical and scientific knowledge with commercial facilities, is equipped to play an important and previously unfilled rôle in behalf of inventive genius and industrial progress in the United States.

THE AWARD OF THE PRIZE OF THE RESEARCH CORPORATION TO DR. ABEL

By CARL A. L. BINGER

HOSPITAL OF THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH

In all fields of man's activity there are free spirits who stand above the others by the fresh fearlessness of their approach to life. These often are the men who, like Alice, are ready to believe six impossible things before breakfast. And such a one is John J. Abel, whose somewhat prosaic title—professor of pharmacology at the Johns Hopkins Medical School—may not suggest that he and Alice and The White Knight and The Mad Hatter are really cut from the same cloth.

It was recently announced that Dr. Abel has been awarded the Research Corporation prize amounting to $2,500 for "outstanding contributions to the cause of science without profit to himself."

To understand why Professor Abel was given the first award one should, of course, know something of the function of the glands of internal secretion and something about the enormously complex chemical problems involved in isolating the active principle of any one of these glands. This has been Professor Abel's main scientific objective: To isolate from one of the important hormones of the body a chemically pure crystalline substance, a substance of known composition and structure, which can be synthetically prepared, and which, when injected into the body, will reproduce the effects of the natural hormone—effects usually profound in their significance and often altering the appearance and even what might be called the "personality" of the organism.

From the days of the ancients these

small endocrine glands and their secretions have attracted the attention of physicians and natural philosophers. But not until the latter part of the last century did their chief functions and interrelations begin to present themselves. In the four years 1887 to 1891, our knowledge was born of the hypophysis in relation to acromegaly, that bizarre disease in which there is gigantic overgrowth of the long bones of the body; of the thyroid gland and the attendant symptoms of its over and under function; of the parathyroids in relation to tetany; of the pancreas in relation to diabetes, and of the internal secretion of the gonads which at puberty determines the appearance of the secondary sexual characteristics. These observations, often made by clinicians at the bedside, presented problems for the labors of physiologists and chemists. Professor Abel's contributions to the chemistry of epinephrin, now commercially known as "adrenalin," the active principle of the adrenal gland, are the most important in this field.

Latterly he has turned his devoted attention to the chemistry of the secretion of the posterior lobe of the pituitary gland, and it is for this work that he has been so justly awarded. The pituitary gland is a small structure located in the brain which is divided on the basis of embryological and histological differences into an anterior and posterior lobe. These structural differences we know now are associated with differences in function. The anterior lobe presumably elaborates a secretion which has to do with metabolism and growth, particularly skeletal growth, and the deposition of fat. It is, however, the active principle of the much smaller posterior lobe of the gland which Professor Abel has striven to isolate. This secretion contains what is called an oxytocic-pressor principle which has the important function of causing contraction of smooth muscle fibers in the body. Since smooth muscle fibers are widely distributed throughout the vegetative organs, a substance which causes their contraction will naturally produce physiological changes of the greatest consequence to the organism. Some of the characteristic responses to this oxytocic-pressor principle are contraction of the uterus, prolonged rise in arterial pressure with constriction of the peripheral arterioles and capillaries, certain characteristic changes in respiration and a very important antidiuretic action which has been found to be of great practical value in the treatment of an obscure condition known as diabetes insipidus, which is characterized by a harassing and excessive thirst and an enormous fluid elimination. Professor Abel has succeeded in isolating a tartrate of highest purity which, though perhaps not yet a single chemical individual, still is a substance very much purer and more potent than any heretofore prepared.

It does not require professional knowledge of these matters to appreciate the value of such labor, and to realize that here is an effort to inquire into the very essence of the nature of the organism, and to relate anatomical qualities and physiological functions to chemical structure. It is with such knowledge that we can begin to think creatively about the organism as a whole and to modify the course of its development. Only a scientist can realize how heroic are the labors required for such work, and what bold imagination is essential to attempt it. Little surprise, then, that Professor Abel was given the prize.

He has won most of the important academic distinctions, but he had a prize of prizes given him from the start—the quality of perpetual youth in his enthusiasm and patience, the ability to labor prodigiously, but never to tread the treadmill of science. He is always eager, slightly whimsical, generous and untrammeled. He has a Hippocratic devotion to his teachers, Carl Ludwig, Schmiederberg and others, and happily he inspires in his pupils and collaborators the same profound devotion.

THE SCIENTIFIC MONTHLY

MARCH 1926

THE ORIGIN OF SPECIES, 1859–1925 [1]

By HENRY FAIRFIELD OSBORN

HON. D.SC., YALE UNIVERSITY; RESEARCH PROFESSOR OF ZOOLOGY, COLUMBIA UNIVERSITY

Cuvierian. Cuvier n'est-il pas le plus grand poëte de notre siècle? Lord Byron a bien reproduit par des mots quelques agitations morales; mais notre immortel naturaliste a reconstruit des mondes avec des os blanchis, a rebâti, comme Cadmus, des cités avec des dents, a repeuplé mille forêts de tous les mystères de la zoologie avec quelques fragments de houille, a retrouvé des populations de géants dans le pied d'un mammouth. Ces figures se dressent, grandissent et meublent des régions en harmonie avec leur statures colossales.—Honoré de Balzac: La Peau de Chagrin.

Darwinian. Variation, when we observe it carefully, appears to be aimless. The transmission of acquired characters is unproven, and must certainly be incredibly slow in most cases, if it does occur. We may justifiably adopt the working hypothesis that evolution has been due solely to fortuitous variation and the action of selection on its results. But we must remember that this is still only a working hypothesis. —J. B. S. Haldane: "What does Darwinism amount to?" *The Saturday Review*, Jan. 3, 10, 1925.

Batesonian. The many converging lines of evidence point so clearly to the central fact of the origin of the forms of life by an evolutionary process that we are compelled to accept this deduction, but as to almost all the essential features, whether of cause or mode, by which specific diversity has come to be what we perceive it to be, we have to confess an ignorance nearly total. . . . That particular and essential bit of the theory of evolution which is concerned with the origin and nature of species remains utterly mysterious.—William Bateson, 1921.

The Law of Evolution

The opening of this superb museum, named after its original benefactor, George Peabody, inspired by the monumental labors of Othniel Charles Marsh between 1851 and 1899, filled with Marsh's unique collections and dedicated to the furtherance of research in vertebrate paleontology, marks an epoch in the development of vertebrate paleontology in America.

Led by Thomas Jefferson, at once naturalist and president of the United States, the pioneers of this historic branch of biology worked their way into the then far west of the Ohio River. Beyond, across the Missouri and the Mississippi, stretched the wonderland of the plains and mountains, awaiting the founders of our science, Joseph Leidy (1823–91), Edward Drinker Cope (1840–97) and Othniel Charles Marsh (1831–99). These three paleontologists entered the broad geologic horizons exposed to the eye by millenniums of aridity, far surpassing in richness and content any of the fossil horizons which in the previous century had made Europe the home of the science of paleontology, or the

[1] Delivered at the opening of the new Peabody Museum of Yale University, December 29, 1925. The third of a series of addresses on the origin of species, the first having been "The Origin of Species as revealed by Vertebrate Paleontology" and the second "The Origin of Species, II," presented to the National Academy of Sciences, April 28, 1925, and November 11, 1925, respectively.

Siwaliks of southern Asia as explored by the great Falconer, and only recently challenged in richness by the vast arid stretches of Mongolia, the latest scene of American energy and enterprise in exploration.

Under the uniform environmental stimulus of our virgin Rocky Mountain region nothing could be more divergent than the methods and the life work of these truly great scientists: Leidy, of the German spirit, broad, deep, unassailable in point of fact, the last naturalist to cover life from the Protozoa to Man; Cope, of the Celtic spirit, eager, impetuous, hasty both in observation and in generalization, a genius in classification, natural philosopher of the school of Lamarck, voluminous writer and pamphleteer; Marsh, of the English spirit, a limited writer, deliberate and calculating like Leidy, energetic in discovery and detection of the most significant point in a fossil, glowing with enthusiasm for paleontology, lavish like Cope in personal expenditure, soon surpassing both his rivals in worldwide fame. Aided by Oscar Harger, Marsh was the first to discover and connect up important missing links in the birds, in the horses and in many other chains of vertebrate life so eagerly sought by Darwin and his great proponent Huxley. While eager and fruitful in establishing long lines of descent and new groupings in classification Marsh concerned himself little about philosophy or about the causes and factors of evolution which so constantly occupied the mind of Cope. Endowed with Marsh's talent for seeing and doing the most important thing first, the Peabody Museum, which we now rededicate, became the Mecca for the evolutionists of Europe, and Yale University the most famous center of vertebrate paleontology in the world.

Vertebrate paleontology, from 1847, the date of Leidy's first paper on "The Fossil Horse of America," to 1897–8, the date of Cope's "Syllabus of Lectures on the Vertebrata," through the very diversity of the genius of these three men firmly established the truth of the Lamarck-Darwin theory of evolution.

Thus between 1859, the date of "The Origin of Species," and 1879, *evolution was firmly grounded as a Law of living Nature, and found its place permanently beside the Law of Gravitation of Newton!* In view of the widespread reluctance in America to accept evolution as a law and the tendency to treat it rather as a theory, let us cite Baldwin's definition of "law":

> *Law* (Lat. *lex*, Ger. *Gesetz*, Fr. *loi*, Ital. *legge*): Any formulation of sequences which from demonstration, experimental proof, successful application, or for any other reason, is accepted as having the highest degree of probability. . . . Law is commonly compared with HYPOTHESIS and THEORY just in this, that these latter terms carry less than the highest probability, and are still in waiting for the demonstration, crucial testing, or final observation which, by conferring what amounts to certainty, raises them to the dignity of law.

The Seven Principles observed in the Origin of Species

Not only the law but several of the subsidiary principles of evolution, which from the time of Aristotle (389–322 B. C.) had been conceived and developed in human anatomy, in zoology and in comparative anatomy, became firmly established through repeated verifications in past and present time. These subsidiary principles prove to be universal not only in individual development and experience and in racial evolution and progress but in the social and spiritual life of man. Baldwin thus defines the word "principle" in its bearing on science in general:

> *Principle* (Lat. *principium*, commencement, beginning: trans. of Gr. ἀρχή, beginning, authority): Ger. *Princip*; Fr. *principe*; Ital. *principio*. Scientifically, it is the law through which

a diversity of facts, otherwise unrelated and unexplained, are classified and interpreted: opposed to *datum*, brute fact, or "mere" fact. . . . Greek philosophy began with the search after the principle in the literal sense; that original reality (a) from which other things are derived, and (b) out of which they consist. In the sense (a) it was implicitly or explicitly dynamic, a force, a causal power; in the sense (b) it was static, an element of subsistence. The first meaning led up to Aristotle's form (ειδος) as a principle; the second to his matter (ὑλη).

Briefly, these subsidiary principles discovered and formulated in zoology as confirmed and amplified in paleontology are five in number: *First*, the principle of individual adaptation or reaction to changes of motion or function which invariably precede changes of form, as first observed by Aristotle and finally confirmed by the experimental observations of Arbuthnot Lane and Felix Regnault; *second*, the principle of development through use, of degeneration through disuse, of balance through unchanged or static function. These two principles were understood and expressed by Goethe in the pre-Lamarckian year 1784, when as a brilliant novitiate in human and comparative anatomy he was on the very threshold of evolution:

Thus by the animal's form is its manner of living determined;
Likewise the manner of life affecteth every creature,
Moulding its form.

Third, the principle of Von Baer in embryology and of Hyatt in paleontology of acceleration or the hurrying forward of characters in development and in evolution, and of retardation or the slowing down of characters, according to juvenile or adult needs in the struggle for existence; *fourth*, the principle of individual and racial struggle for existence and individual and racial survival of the fittest; *fifth*, the Lamarck-Darwin principle of ébranchement, of divergence, the adaptive radiation of Osborn, permeating the diversity of the plant and animal world. These five great principles, all alike discovered in zoology, were confirmed and ratified in paleontology as the principles of progression and of retrogression, manifested first only in the individual and finally in the race. They are the coefficients both of individual development and of racial evolution, or phylogeny, as set forth in what Osborn has termed tetraplasy and tetrakinesis.

Coefficient. *a.* Cooperating; acting in union to the same end. *n.* That which unites in action with something else to produce a given effect; that which unites its action with the action of another.

But these five coefficients are not all the process, for in the nineteenth century the paleontologists found new fields to conquer wholly beyond the vision of the zoologist; down through the ages he alone became the *camarade intime* of evolution, of the secular forward and backward marching hosts of separate characters, and the new problem presented itself as to how these separate characters arise and conduct themselves. Whereas to the zoologist every minute mechanical part of every animal is still and dead, to the paleontologist every minute part is alive and moving, slowly unfolding in the original sense of the Latin *evolvere* (*evolutio*), just as to the vision of the embryologist individual development is an *unfolding* of the potency of the germ.

Thus the paleontologist discovers two entirely new and additional principles, a sixth and seventh, namely, *sixth*, the principle of continuity, of continuous and unbroken advance or recession of each character from invisibility into visibility, and, *seventh*, closely connected therewith, the principle of rectigradation, of the continuous rise of each new organ out of heredity, passing through stages of increasing mechanical perfection, then perhaps gradually subsiding again into the germ-plasm until it finally disappears.

These seven[3] principles which govern the origin of species in mechanical adaptation also concern genetics, for only through paleontology can we clarify our genetical vision of heredity and distinguish the ripples of "saltation" or "mutation" from the waves of "evolution," the local currents and vortices of "variation" from the rise and fall of the tide of great characters. The minute fossilized tissues of the ivory tusks of the mastodon and the stupendous "thunder-saurian" *Brontosaurus* displayed in this museum are alike mirrors and "phenotypes" of the evolving germ-plasm out of which they once developed. The stages in the evolution of the horse, camel, mastodon and elephant, in the largest and in the minutest detail, are mirrors of the evolution of the germ-plasm. If your intellectual tastes incline you to observe the energy of mechanisms within the range of mechanical vision, seek them with Morgan in *Drosophila*, the fruit-fly; if your intellectual predispositions incline you to gaze into paleocrystic mirrors of energy and form, observe the details of ascent from *Eohippus* to *Equus*, of the rise of the Pleistocene mastodon of our forests from the *Palæomastodon* of Oligocene Africa, or the rise of Marsh's giant *Triceratops* from the egg-laying *Protoceratops* of the Desert of Gobi.

Paleontology adds Creation to Evolution

Whether geneticist or paleontologist, you are observing the initial and the terminal phases of a *continuous creative evolution and adaptation of the germ-plasm*, for paleontology forces upon us this new creational definition and conception of evolution, namely, of a *continuous creative unfolding of life fitted to a continuously changing environment*.

Is it not remarkable that neither through philosophy nor through speculation but through paleontologic research the original Latin word "evolution" becomes inadequate and the old Sanskrit word √ *kar* reasserts itself?

> *Create* (Lat. *creatus*, make, create, akin to Gr. *κραίνειν*, complete, Skt. √ *kar*, make). I. *trans.* To bring into being; cause to exist; . . . II. *intrans.* To originate; engage in originative action.

Bergson's term "creative evolution" comes nearer expressing the actual truth of the biomechanical aspects of evolution observed throughout a half-century, but it contains teleologic or vitalistic implications which we do not accept.

This new definition is made not to please the still surviving "special creationists" but to express the two new principles of evolution discovered in paleontology, namely, the principle of *continuity* and the principle of *rectigradation*—the one a denial of mutation in biomechanical evolution, the other a denial of fortuity in biomechanical evolution. It is the answer to Haldane (1925) and to Bateson (1921).

Historic Explanations and Interpretations

Before further clarifying these seven zoopaleontological principles let us glance at the historic explanations of evolution, which are as old as philosophic Greek thought (640 B. C.–1600 A. D.); they are all summed up in the great names of Buffon, of Lamarck and of Darwin, who were the first to formulate these historic explanations adumbrated by the ingenious Greeks. Lamarck and Darwin found themselves in an intellectual world very hostile to evolutionism;

[3] This is a concise restatement of Principles I–IX elaborated in "The Origin of Species as revealed by Vertebrate Paleontology," the author's first address on this subject, presented to the National Academy of Sciences April 28, 1925. Printed in full in *Nature*, June 13 and 20, 1925.

they could not put forth the infant evolution theory without an explanation acceptable as in some degree adequate to offset the contemporary creationism; they were alike too eager to explain and were over-reliant on what we now know to be only partial explanations.

The essence of the rival Lamarckian and Darwinian theories can be distilled into modern economic phraseology when we imagine the germ-plasm as our life-capital, for Lamarckism, in economic terms, treats the germ-plasm in this sense. In Lamarck's confident words:

> *tout ce qui a été acquis,* tracé ou changé dans l'organisation des individus, pendant le cours de leur vie, est conservé par la génération et *transmis aux nouveaux individus* qui proviennent de ceux qui ont éprouvé ces changements. [Italics our own.]

In Darwin's original and equally confident statement:

> *any minute variation* in structure, habits, or instincts, adapting that individual better to the new conditions, would tell upon its vigour and health. . . . Those of the offspring who inherited the variation *would have a better chance of surviving.* [Italics our own.]

The germinal capital of Darwin varies in each individual, and the variation which best suits the environment is added to the capital of the survivor. As popularly worded here, these theories of Buffon, Lamarck and Darwin, usually regarded as contradictory, are really complementary; they cooperate, they do not conflict, they are not the whole explanation but only a fraction of the explanation of animal and human progress in evolution.

Yet post-Darwin seekers after explanations and causes came in great waves of opinion and founded schools of followers. Darwin and Wallace strongly condemned Lamarck and presented natural selection so forcefully that it held full sway from 1859 to 1870; then Lamarckism was revived in the minds of Spencer, Cope and even of Darwin himself, until in 1880 Weismann gave Lamarckism in its original form a *coup de grâce* and revived Darwinism in its purest original form. In 1890 Darwinism found a new champion in DeVries, but natural selection appeared under a new name as the "mutation theory"; from 1890 to 1924 this mutation theory enjoyed the following of a great school of mutationists and, in turn, the new support of genetics, until Bateson, founder of the genetic school, declared that *we know neither the cause nor the mode of the origin of species,* and crushed the hopes of mutationists as well as of geneticists to give an acceptable answer to the age-old problem of the origin of species.

Theories of the Origin of Species Replaced by Discovery in Paleontology

Meanwhile some paleontologists were speculating while others were quietly devoting themselves to gathering harvest after harvest of facts about the modes and causes of the origin of species. There followed a series of discoveries which put new and unforeseen tests upon the historic theories and explanations.

First, the principles of *phylogeny,* including the actual lines and modes of animal descent, which had been sought in vain by zoology and comparative anatomy, were discovered in one family of mammals after another by intensive research into the minute details of change. Thus in Europe Depéret and Stehlin were ferreting out "ascending and descending mutations" in the sense of Waagen (1869), and in America we were microscoping the four-million-year ancestry of the horses, of the rhinoceroses and titanotheres, finally of the proboscideans, which had been broadly sketched in the telescopic restorations of Leidy, Cope and Marsh. There was revealed a minuteness of realistic detail which may soon be amplified by the still-

sought Tertiary ancestry of man, of which we know the branches and the twigs but not the main trunk.

Second, as a unique result of paleontological research we perceive evolution as a *secular* phenomenon, a process of the ages which, measured either by geology or by the radium content of the rocks, is infinitely longer than either Lamarck or Darwin conceived; Lamarckism in large part holds true as a cause of *secular* evolution, just as Darwinism holds true as a potent cause of secular evolution. On the other hand, paleontology denies absolutely the origin of species according to the original conceptions and literal interpretations of either Lamarck or Darwin. In claiming that all that is acquired is transmitted Lamarck was overconfident, as Darwin was overconfident in claiming that every variation, however slight, favors the chance of survival.

Third, the grand result of paleontological research was to transfer, from the field of reason, imagination and speculation, to the field of direct observation the whole question of the modes and methods of evolution and the whole problem of the manner in which new specific adaptations originate and of the details by which new biomechanical species are constantly created. I refer to such biomechanical adaptation as the elongated neck of the giraffe, the classic case cited by Lamarck and Darwin.

In this and many other examples it appears that "species" and "adaptations" are practically synonymous terms, as may be clearly seen in the history of these two terms, from Aristotle to Linnæus. The origin of species and the origin of adaptations are of the same significance, for every "species" is an ensemble of countless adaptations in various stages of rise and decline. What Aristotle 300 B. C. called an adaptation, Linnæus in 1758 called a species. When Aristotle in his "History of Animals" and in his "Physics" debated the natural causes of adaptations he had in mind the same structures and functions as those which Linnæus used in defining his species. For example, the celebrated "survival of the fittest" passage in Aristotle's "Physics":

> What, then, hinders but that the parts in Nature may also thus arise? For instance, that the teeth should arise from necessity, the front teeth sharp and adapted to divide the food, the grinders broad and adapted to breaking the food into pieces. . . . It is argued that where all things happened as if they were made for some purpose, being aptly united by chance, these were preserved, but such as were not aptly made, these were lost and still perish, according to what Empedocles says concerning the bull species with human heads. . . . Nature produces those things which, being continually moved by a certain principle contained in themselves, arrive at a certain end.

For example, again, Linnæus (1758) defines the anthropoid ape known as the orang:

> *Simia: Dentes Primores* IV, approximati.
> *Laniarii* solitarii, longiores hinc remoti.
> *Molares* obtusi.
> *Cauda nulla:* Simiae *veterum.*

To resume the bearing of paleontology on explanation and interpretation, from the very dawn of human ambition to observe and interpret nature there have been only two broad solutions to the problem of adaptation and of the origin of species: the supernatural and the natural. Aristotle adopted the natural and fully debated the essential idea of both Darwinism and Lamarckism; to Aristotle's formulation of Lamarckism Brooks (1899) has called our attention:

> Herbert Spencer tells us that the segmentation of the backbone is *the inherited effect of fractures, caused by bending,* but Aristotle has shown ("Parts of Animals," I. i.) that Empedocles and the ancient writers err in teaching that *the bendings to which the backbone has been subjected are the cause of its joints,* since the thing to be accounted for is not the presence of joints, but the fitness of the joints for the needs of their possessor. [Italics our own.]

Since 1859 there have been hosts of explanations and hypotheses overworked by various schools of opinion. Darwin's word "variation" has been a will-o'-the-wisp leading biologists into many morasses, with its many modern mutant terms, "variation," "selection," "mutation." Paleontology enables us to winnow out the wheat from the chaff in all these partial explanations of the origin of species, for it demonstrates that hosts of variations such as those set forth by Bateson in the year 1894 in his "Materials for the Study of Variation" are wholly insignificant in the evolution process.

In our natural tendency to follow the line of least resistance and to seek explanations and *causes before facts,* may we not guard the advice of Pliny as quoted by Fourtau:

> Pline l'a dit, et on ne saurait trop le répéter; il convient d'abord de bien exprimer ce qui est, avant de remonter aux causes: *Quærere tu causas, mihi abunde est si expressi quod efficitur.* Je m'estimerais très heureux, si, dans ce travail, j'ai réalisé le sage précepte du naturaliste romain.

The facts of paleontology throw a new and critical light on the relative value of the three historic explanations as to the causes of adaptation, namely, those of Buffon's direct action of environment, of Lamarck, and of Darwin, which alike turn on the question of inheritance or transmission of individual adaptation. Paleontology cuts like a two-edged sword on any theory of immediate action.

First, inasmuch as marvels of origin are due to individual adaptation, which may by inheritance furnish the key to evolution, the idea running through the minds of Aristotle, Lamarck, Spencer and Cope is shown by paleontology to be illusory, for individual adaptation now proves to be a *secular* rather than immediate cause of the origin of species as Lamarck suggests. Even if we were to demonstrate the immediate, prompt and entire inheritance imagined by Lamarck, the majority of new biomechanical adaptations observed in paleontology would still remain wholly unaccounted for.

Second, there is the historic idea of Buffon as to the inheritance of the direct action of new environment; it is true that new species, as they are observed by systematists, suddenly or gradually originate in this way, as shown by Crampton in *Partula,* because in the laboratories of nature the new environment endures. The "species" of the systematist is not the same as the "species" of the geneticist, but nature does not make this distinction. A host of field naturalists have long since proved Buffon's principle to be very general among birds and mammals. Another host of experimentalists in America, England and Germany are demonstrating the immediate origin of new species in *le monde ambiant* of chemical and physical experiment. So far as we see at present such origin of the species of systematists is chiefly in biochemical adaptations in which the germ may be affected permanently by a molecular or atomic saltation. On the contrary, from the secular point of view of paleontology the germ-plasm or *keimplasma* of Weismann is at once the most stable and the most plastic element in life; it offers stubborn resistance to both Lamarckian and Buffonian influences, such as we observe day by day in nature and in the laboratory.

On the affirmative side paleontology proves that in the long run of geologic or secular time both Buffon and Lamarck, as well as Darwin, were right in their main conceptions: organs starved by unfriendly environment finally disappear; organs which do not pay their way and are starved by disuse slowly drop out of the germ-plasm; vitally essential organs are either absolutely stable or progressive. Why not therefore concede the truth of the great

conceptions of Buffon and Lamarck, even if immediate inheritance by the germ is disproved in the great majority of cases? Why not concede the still greater conception of Darwin, misled as he was as to time by the marvelously rapid evolution of the germ-plasm witnessed in artificial selection? Whereas neo-Darwinians have been as impatient as neo-Lamarckians in looking for instantaneous results in the first or the few following generations, paleontology proves that the deferred secular action of natural selection is as firmly established as the deferred secular action of both the Buffon and the Lamarck factors. Both in progressive and retrogressive organs paleontology proves that every organ needs the sustaining and standardizing power of selection as it acts to-day in swarms of a trillion mosquitoes, in herds of a million bison, in flocks of a thousand ducks.

Rectigradations and Continuity await a New Conception

But if we grant that Buffonian, Lamarckian and Darwinian factors were all true even in this secular sense, if we grant that the living and the lifeless environment, the adaptation, habit and survival-of-the-fittest variations combine continuously to produce new adaptations and species, do we then account for all we paleontologists observe in the modes of origin of species in ascending and descending phyla of all the animals we have been able to study?

We answer, "Certainly not." Buffonism, Lamarckism and Darwinism combined would account for only a small fraction of what we observe.

The unaccounted residue of creative evolution is by far the larger—is, in fact, infinitely the larger—part. Here is the critical point in modern biology where we pass from the rational, *i.e.*, all that is within the range of observation, experience and reason, to the super-rational, namely, to the ultimate unknown causes of what Lucretius called "the firm and undeviating order," when he quoted his master Aristotle in his famous refutation of Democritean fortuity in nature:

> Order and a firm and certain constitution or being are far more obvious in celestial natures than in us, but an uncertain, inconstant, and fortuitous condition is rather the property of the mortal race.

This discovery of the "firm and undeviating order" in the origin of species with which paleontology replaces all the chance explanations of adaptation from Empedocles to Darwin is the supreme service which paleontological research renders to biology. It is into this new and mysterious field, into this new teleology that the paleontologist of the future may venture. Perhaps within the very walls of the Peabody Museum, where adaptation is set forth so transparently by the master hand of Lull, some young Aristotle or Darwin may find his inspiration to grasp the problem of the origin of species which has baffled man for two thousand five hundred and eighty-five years.

Are we right in concluding with Balzac in his brilliant *éloge* to Cuvier that paleontology comes very close to philosophy, the science of the causes and origins of things? Was the author of *La Peau de Chagrin* right in his prophetic vision of the then infant science, the *paléontologie* named by Cuvier?

> Il réveille le néant sans prononcer des paroles artificiellement magiques; il fouille une parcelle de gypse, y aperçoit une empreinte, et vous crie: "Voyez!" Soudain les marbres s'animalisent, la mort se vivifie, le monde se déroule! Après d'innombrables dynasties de créatures gigantesques, après des races de poissons et des clans de mollusques, arrive enfin le genre humain, produit dégénéré d'un type grandiose, brisé peut-être par le Créateur.

CHANGING LEVELS OF THE GREAT LAKES

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THE present very low levels of our "Unsalted Seas" and the effect of the diversion at Chicago of Lake Michigan water to Mississippian drainage is of scientific and economic interest to the public, and will remain a matter of lively interest and dispute until the hydraulic and commercial questions are adjudicated. A brief review of the scientific elements and of the engineering data is pertinent.

The subject is one of considerable complexity. The natural changes in the height of the water surfaces involve several factors, in meteorology, hydrography, physiography and geology. And when we have interference with the natural flow by changes in the outlets, and especially by new, artificial outlets, there is added the interesting element of hydraulic engineering. And with these comes the stress of commercial rivalry between great cities and large sections of the continent.

The charts of the United States Lake Survey (Detroit, Michigan) show graphically the eccentric and striking changes in level of the five lakes since 1860, or for the last sixty-five years. Beyond the quite regular annual fluctuation of high water in summer and low in winter, usually about one foot, there is no regularity or clear periodicity. The greater changes of level through several, or many, years are certainly due to meteorologic or climatic conditions. These fluctuations are so variable and so unlike in the different lakes that it is not practicable to make predictions of unusual changes.

In study of the scientific data relating to the lake levels a single lake should first be taken as an independent waterbody or without any influence from tributary lakes. Lake Superior may be an example. The dominant factors of weather and land surfaces are varied and interrelated. Water is added to the lake only by precipitation, rain or snow, over the drainage basin. Such supply may be directly into the lake or indirectly by the inflowing streams. The whole supply varies greatly in time of year and from one year to another, according to the variable climatic conditions of our middle latitudes. To the extent that the precipitation is snow the run-off from the land awaits the uncertain melting, which may all occur in the spring. And this supply from the land drainage will also vary in time according to the condition of the ground. If the soil is receptive, like a forest area or a tilled surface, the water is partially retained for gradual release. If the slopes are steep and bare or the ground is saturated or is frozen the run-off is prompt. Frozen streams and ice-jams have an opposite effect. Moreover, these factors may vary in different years, or every year, between the several drainage areas of the lake, according to latitude, the topography or surface slopes and the soil characters. In the case of the Great Lakes the time of the winter and spring run-off and its volume may be very different on the Canadian side of the basin from that on the south side.

Removal of the water is not only by the visible overflow through the outlet but largely by the invisible evaporation. This is the most variable and the critical factor. Over the Ontario basin it is estimated that one half of the precipitation

is carried away by the air, as the "fly-off." This depends, of course, on the variable elements of the weather, as temperature, sunshine and humidity. A dry, warm and clear summer will rapidly lower the lake surface, while a cold, cloudy, wet and humid season will effectively inhibit evaporation. In a large basin, like that of any one of the Great Lakes, these meteorologic conditions may be unlike in different parts of the area, even during the same season.

One element in the hydraulics of the single lake tends to check extremes in the surface levels. Higher surface of the lake increases the velocity of flow in the outlet, and the faster outflow tends to lower the surface level, while a low level of the lake has opposite effect. But this element is not important and is greatly overbalanced by other factors.

For an independent lake with no human interference it is evident that any considerable variation in the surface elevation is an effect of the complex and variable atmospheric conditions along with the characters of the land of the drainage area. One important factor, elusive and unmeasured, is evaporation.

Now, when we have to consider a chain of lakes, it is evident that any lake is subject not only to its own variables but also to those of all other lakes which are tributary to it. The Michigan-Huron body has the added variant of the great Superior. Lake Erie feels the changes in the three upper and larger lakes. And Lake Ontario, with the smallest area, is subjected to the total net vicissitudes of all the lakes.

As the Great Lakes collect from a large drainage territory, which commonly has quite different weather and stream conditions, it appears that excesses in some areas may be more or less balanced by contrary effects in other areas. Such moderating factor applies especially to Erie and Ontario.

Some causes of temporary, but sometimes sudden and surprising, changes of water level should be described. Strong and steady winds may sweep the water from the windward to the lee side of a lake so as to produce great differences of level. In Lake Erie such difference is said to have been twelve feet, and, aided by the damming effect of ice, with northeast winds, have left Niagara Falls practically dry. Occasionally a sudden and decided change of water level along shore is puzzling and mysterious to the people and causes wild speculation. These quick changes in calm conditions are produced by passage across the lake of atmospheric waves of different pressures. A decided low-pressure area or whirl, cyclonic in nature and perhaps tornadic in intensity, may so lower the atmospheric pressure beneath it as to produce a rise or bulging of the water surface. The greater pressure in the surrounding area pushes the water in from all sides. A barometric "low" or cyclonic whirl of not uncommon intensity might cause a diminution of pressure equal to one half inch of the mercury column; and this implies a decrease of weight of one half million tons on a square mile. On the shore the first effect is usually the mysterious withdrawal of the water, followed by a "sea wave," and later a succession of dying-out waves. Such changes of level, due to the passage of atmospheric highs and lows, are called "seiches." Minor fluctuations of this nature are frequent, and large lakes in middle latitudes are rarely at rest for any considerable time.

The Great Lakes are also affected by the lunar tides, but these are so weak that they are masked by the seiches and wind currents.

Human Interference

Thus far reference has been only to the agencies and processes of nature.

But these are seriously modified by human occupation of lands surrounding the lakes, resulting in deforestation, soil cultivation and damming of streams. Contrary to popular belief deforestation has little effect on precipitation, which is dependent on conditions in the higher atmosphere. But removal of the forest cover is effectively injurious by increasing the rapidity and amount of the flood run-off, especially on steep and bare slopes. Agriculture has the opposite effect, by producing porosity of the soil, thus holding back the precipitation and increasing the evaporation. Damming of streams and production of ponds or reservoirs has some effect in reducing flow into the lake, by increasing the surface for evaporation. Use of water for irrigation effectively reduces the inflow by increasing evaporation; but this is negligible in the Great Lakes region. Extension of farming has undoubtedly reduced the flow of streams into the lakes; and the total effect of human occupation of the basin of the Great Lakes has been a permanent lowering of the lakes. This may explain, at least in part, the general fall of the lakes during forty years. The steady drop during the last six years, amounting to over two feet, must be blamed on the weather, as described below. Changes of climate through long periods are recognized, but they are much slower in effect than the measured changes in the lakes.

The Geologic Element

Natural geologic processes are responsible for both the production and destruction of all lakes. Ponded water, or lakes, is not a normal feature of natural drainage. Streams do not make lakes. Created in any manner lakes are short-lived and evanescent features, measured in geologic time. Before the Glacial Period, which was only yesterday, speaking geologically, there were few, if any, lakes in North America. There are no lakes to-day in the southern states outside of Florida. The ox-bow lakelets in river floodplains are not in the same category. The scores of thousands of lakes and tarns in the glaciated territory of the northern states are due to the blocking of stream courses by glacial drift. In time they must disappear, if nature were left alone.

Lakes are extinguished by the down-cutting of their outlets and by the filling of their basins. The latter is done by inwash of detritus, sand, clay and lime, and by vegetal growth. The operation is usually slow but certain. We see some rapid work of filling in the many abandoned mill sites on our streams. The extensive plains at the heads of many lakes, as the Finger Lakes of central New York, are excellent examples of recent lake filling, by the inwash of the inlet streams. The Great Lakes, with the possible exception of Superior, came into recent existence as an effect of the work of continental glaciers. Their life has been too short, only scores of thousands of years, for the destructive processes, down-draining and filling, to be visible.

One geologic force has had great effect on the levels of these young lakes. The normal level of a lake is determined, it is evident, by the attitude or elevation of its point of overflow, or outlet. Since the lakes were formed their outlets have shifted in vertical relation to the basins, due to the tilting uplift of the glaciated territory. The area had been depressed by the weight of the ice caps, which were perhaps two miles in depth. With the removal of the weight the land has risen, probably recovering only a part of its original elevation. In the states and in southern Canada the land rise has been a slanting uplift, being on the south side of the doming. For example, at Rochester, New York, the post-glacial uplift is 250 feet. On the north boundary of New York the rise has been 740 feet, and in

southern Quebec something over 1,000 feet.

Lake Ontario was initiated at sea level. It was the immediate successor of Gilbert Gulf, which occupied the Ontario basin and was confluent with the sea through the Champlain-Hudson estuary. By the tilting rise of the land, following the melting of the Quebec ice sheet, the district of the Thousand Islands was raised out of water, forming a barrier in the St. Lawrence Valley. The water imprisoned behind this dam became the Lake Ontario, and its elevation has risen from zero to 246 feet by the rise of its outlet. Lake Ontario is the latest great physiographic feature in America, with a life history of perhaps 10,000 years.

It is possible that Lake Superior was originated by a down-warping, or basining, of the earth's surface. But the other Great Lakes as we now see them are doubtless the indirect effect of glaciation. Their basins were portions of great river valleys, carved during the millions of years of preglacial time. The basins were not cut by glacial erosion but have been formed by accumulation of glacial drift in sections of the old valleys; the basins being the unfilled portions. The courses of the ancient streams have been mostly obliterated. By the rise and deformation of the land the lake basins have been tilted and deepened.

The question now arises: Are the lake levels now changing because of continued uptilting of the region? The reply is quite confidently in the negative. Remeasurement of the Lake Survey benches, established fifty years ago, shows no more change than may be attributed to settling of structures and errors of measurement. Any continued tilting uplift would raise the level of Ontario, because its outlet is on the north. This would produce flooding of the south shore. In less degree the same change would affect Erie. But northward uptilting would lower the north shore of Huron, while raising the south end of Michigan. Such changes have not been proven. Either the land movement is too slow to produce visible effects in nearly a century, or it has practically ceased in the region of lakes.

The natural downcutting of outlets in hard rocks is a very slow process, and in the case of the Great Lakes it is a negligible factor in this study.

It has been questioned if the recession of the falls of Niagara might possibly so enliven the flow of the rapids as to have some backwater effect on the level of Erie. This appears extremely improbable. It is admitted that in the geologic future the recession of Niagara Falls may drain Lake Erie.

Comparison of Levels

Thus far our discussion has mostly been on the philosophy of changes in lake levels. Let us now apply the theory to the facts.

Complaints of extremely low water in all the lakes have become both frequent and emphatic. This is confirmed by the gauges and published charts of the U. S. Lake Survey. For the past six years there has been a steady drop in all the lakes, even in Superior. The older record also shows that there has been a general average fall of two feet or over from the levels of many years ago. The graphs of the Survey charts give the details. This lowering of water surfaces and shallowing of depths seriously interferes with the great volume of shipping, and has great commercial, economic and international importance.

Lake Superior, independent of the other lakes and unaffected by the Chicago diversion, has participated in the recent fall, having dropped one foot to 600.8 feet above ocean in March of last year. And this drop is in spite of some control at the outlet. However, it was

as low as that in the springs of 1871 and 1880 and was lower in 1911.

Michigan and Huron were high in the summers of 1917, 1918, being up to 582 feet, A. T., and have been dropping since to 578.23 feet, in January and February of last year, the lowest in their record.

Erie fell in February of last year to its lowest record, 570.46 feet.

Ontario dropped to 244.22 last January. But it was lower in 1895–96, reaching its minimum of 243.41 feet. All the lakes except Superior were low in 1895–1896.

The blame for the present low water has been placed, by many people and newspapers, on the diversion by the Chicago drainage and ship canal. This artificial waterway was opened in 1900, to carry water of Lake Michigan, with the diluted city sewage, over into Mississippian drainage. The canal is designed to carry 10,000 cubic feet per second. The U. S. War Department permitted a diversion of 4,167 c.f.s. and in 1913 sought an injunction to prevent more than that amount. In 1923 the Federal Court granted the injunction, and on appeal to the U. S. Supreme Court the injunction was upheld by decision given in January of last year. The War Department is allowing time for adjustment.

On request of the trustees of the Chicago Sanitary District a board of review, composed of twenty-eight eminent hydraulic and sanitary engineers have reported on some phases of the complex problem. The board finds that the diversion for several years of about 10,000 c.f.s. has caused a lowering in Michigan-Huron of five inches; and a reduction in the flow of Niagara of 5 per cent. Of course this is relatively a small amount when compared with the two to five feet variations of levels. However, it must be admitted that it is a continuous and constant factor in the lowering of the lake levels, and especially effective and hurtful in time of very low water, as at present.

Some part of the fall in Michigan-Huron is attributed to the recent enlarging of its outlet, the St. Clair River, and to the temporary storage in Lake Superior.

There is diversion from Lake Erie by the Welland Canal, the Black Rock Canal and the N. Y. State Barge Canal. This, it is estimated, has lowered the lake four inches. But this diverted flow finds its way into Lake Ontario. The Chicago diversion is the only one that affects the four lakes.

Meteorologic Factor

The annual reports of the U. S. Weather Bureau show that since 1919 (report for 1924 not yet available) the weather was warmer than normal in all the states that border on the Great Lakes, except New York. Also that the precipitation was in general below normal. The higher temperature implies greater evaporation. These facts appear sufficient to account for the acute fall of levels during the last six years. It may be expected that this low stage is not permanent, but will soon be followed by rising levels.

The more permanent average lower levels of later decades, of some two feet, may reasonably be attributed to increasing human occupation and extended agriculture, which has accelerated the critical factor of evaporation. The change in the lake levels is too rapid even in the past fifty years to be an effect of any long-period and universal variation of world climate.

The conclusion appears unavoidable that the present very low levels of the lakes, which is not unprecedented, are not due to any geologic nor physiographic change of the region, nor in any

considerable degree to enlarging of outlets. And it may be admitted that only minor effect can be placed on the diversion at Chicago. The chief cause is certainly meteorologic. It lies in some slight and indeterminate shifting of the great atmospheric currents which flow eastward, at high altitudes, across our latitude; along with erratic behavior of the whirls or cyclones which are responsible for our "weather."

Engineering Data

The Chicago Sanitary District is building an elaborate and expensive system of sewage disposal plants. But the engineering Board of Review recommends that the present diversion by the Chicago Canal should be permitted in continuity; for three reasons: First, that the topographic and physical conditions of the city are of such character that without this flow the flooded streams and storm-water would carry part of the sewage into Lake Michigan; second, that the full canal is desirable for the "Gulf to Lakes" commerce; third, that with easily constructed regulating dams at the outlets of the lower lakes the Chicago diversion will be negligible.

The analysis by the Board of Review of the lowering in Michigan-Huron is interesting as a study in hydraulics. The fall of thirty-one inches is apportioned as follows:

Excessive evaporation and subnormal precipitation	13	inches
Increased flow by the enlarged St. Clair River	8	"
Diversion at Chicago	5	"
Storage and retention in Lake Superior	3	"
Back-water effect by diversion and lowering in Erie	2	"

Chicago has offered to bear the cost of regulating works to control the outflow at Niagara and St. Lawrence, the dams or locks to be designed and built by the U. S. Engineers. Lake Superior outlet has been under partial control for eight years. Such regulation should certainly be extended to all the lakes, regardless of diversion at Chicago or elsewhere. This control would conserve the high waters which now escape and would permanently raise the levels of all the lakes for deeper-draft ships and safer navigation. The dam built by Canada at the Galop Rapids has lifted the level of Ontario six inches.

It is recognized that economic rivalry of the great cities and the conflicting interests of existing and proposed routes of commerce are intent on controlling public opinion and political action. But it should be realized that future commerce will need all the water routes that are possible and that nature will supply sufficient water if it is intelligently conserved.

In the issue of this journal for December, 1924, is a masterly and very interesting article on the hydraulics of the Great Lakes and on their proper control, by the lamented Dr. John F. Hayford; entitled "The best use of the Great Lakes."[1]

The Glacial Warren River

The path of the Chicago Drainage Canal has special geologic interest, because the city has merely utilized the path of a great river of Glacial time.

When the latest ice sheet was waning there was an episode, perhaps some thousand years, when much of the Great Lakes area was exposed to the air, but while the ice sheet yet blocked the two lowest passes for water escape. These are the eastward passes by the Mohawk and the St. Lawrence valleys. The overflow of the copious glacial waters was then forced south by two passes, one through Ft. Wayne, Indiana, to the

[1] The Scientific Monthly, Volume 19, 1924, pages 585–597.

Wabash Valley, the other through Chicago to the Desplaines-Illinois valley. Both courses led to the Mississippi. At length the Chicago outlet robbed the Ft. Wayne outlet and for a long time it carried all the outflow of the Great Lakes area, including western and central New York. This great outlet river, which flowed through the site of Chicago, is called Warren River, after General G. K. Warren, U. S. Engineers, who recognized the splendid channel as the work of a great river, without knowing its history. Deepening this old scourway only a few feet permitted Lake Michigan to outflow again to the Mississippi. The glacial lake which lay in the Michigan Valley and was drained by the Warren River is called Lake Chicago. The lake in the Huron-Erie-Ontario area, which has left good beaches in New York, is also called Lake Warren. Its outflow was across the state of Michigan into Lake Chicago. So the glacial waters of New York helped to carve the low channel at Chicago and ultimately to provide some relief for the great city with the poor location.

The Chicago glacial outlet was abandoned when the receding front of the ice sheet permitted the imprisoned waters to escape eastward to the Mohawk and Hudson valleys, and later by the present flow through the St. Lawrence.

FOSSIL HUNTING IN THE WHITE RIVER BADLANDS

By WILLIAM DRUMM JOHNSTON, Jr.

UNIVERSITY OF CINCINNATI

MAN has retained ontogeneric memories of his first livelihood; of a weary watch by the salt lick, a patient stalk up wind, a spring, a struggle and then the perfect contentment. A full stomach, I can not deny, was the consummation of his labors, but beyond such a homely stimulus as hunger there was something else—the joy of the hunt, a pure emotion, undefiled by cravings of the flesh.

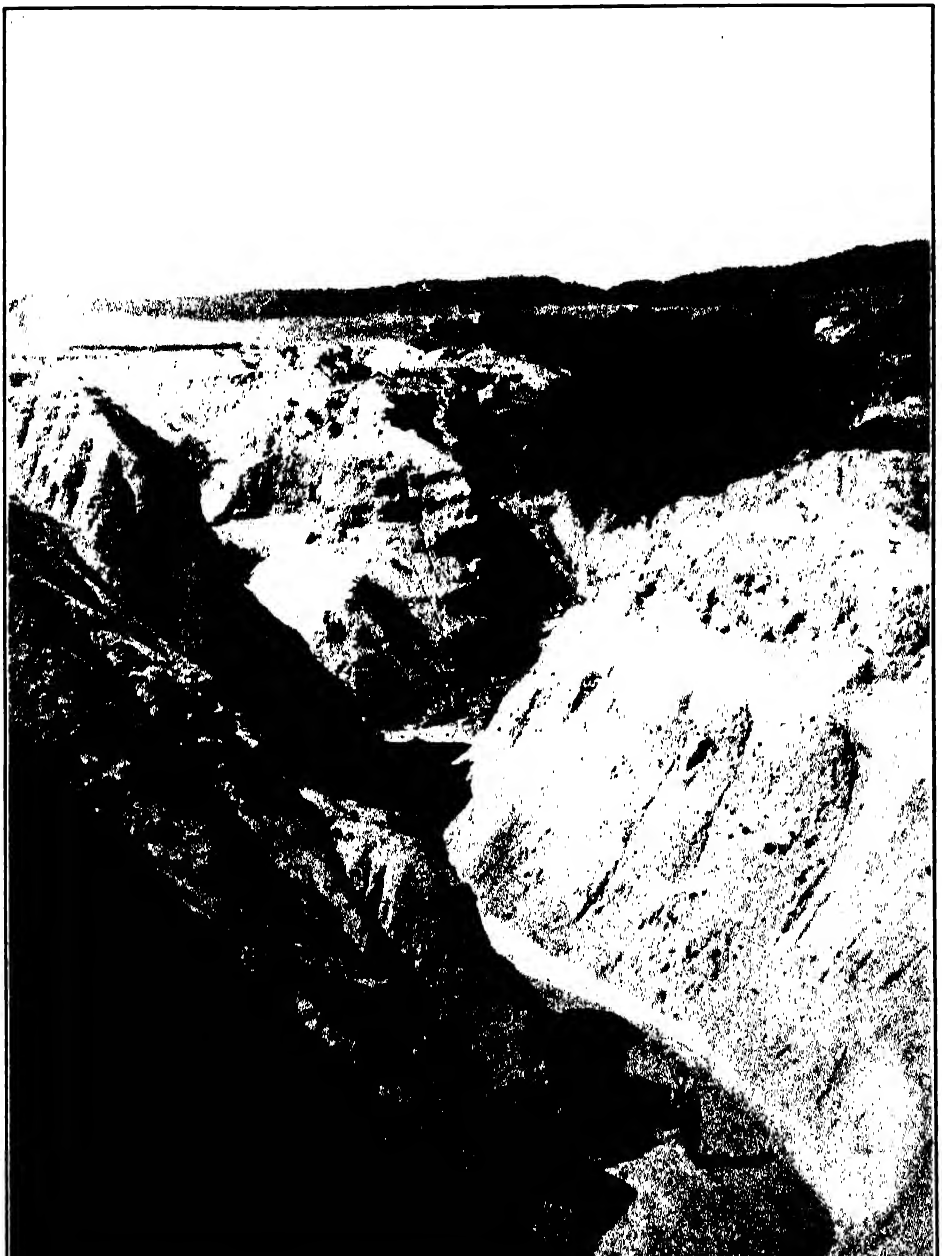
As a child, I have heard my father recount his experiences in a day's shooting, and wondered at the enthusiasm which resulted from so depressing an occupation as spending a cramping day in a damp blind, to be rewarded with only a brace of ducks at nightfall. Later, I wondered at the enthusiasm of a little friend who succeeded in snapping the picture of a red-winged blackbird on its nest of reeds. On one of those boring picnics which are so dear to us, I have watched a painstaking search for four-leaf clovers drag through the afternoon, and with each new manifestation of zealousness in the hunt, I met ardor with apathy, or, at best, with a polite interest. I fear that I scoffed at my hunting friends, and in just retribution, the hunting instinct, which hitherto had reposed with proper decorum in the limbo of my unawakened racial memories, shook itself, yawned once or twice and strode into my consciousness.

With a pick closely akin to those which are used for ice work in mountain climbing, a whisk broom of homely simplicity, a few pointed implements of nondescript character which, to the uninitiated, might pass as a collection of carbon-cleaning tools, I was equipped for the pursuit of the animals which ranged during Tertiary times, some three million years ago, over what is now the White River Badlands, in the corner where South Dakota, Nebraska and Wyoming touch.

Paul Christian Miller, of Walker Museum, the University of Chicago, and I journeyed from Chicago to Harrison in a Ford car equipped with a light truck body, and established a base from which to make our collections at the foot of Pine Ridge in Sioux County, Nebraska, at the edge of the Badlands.

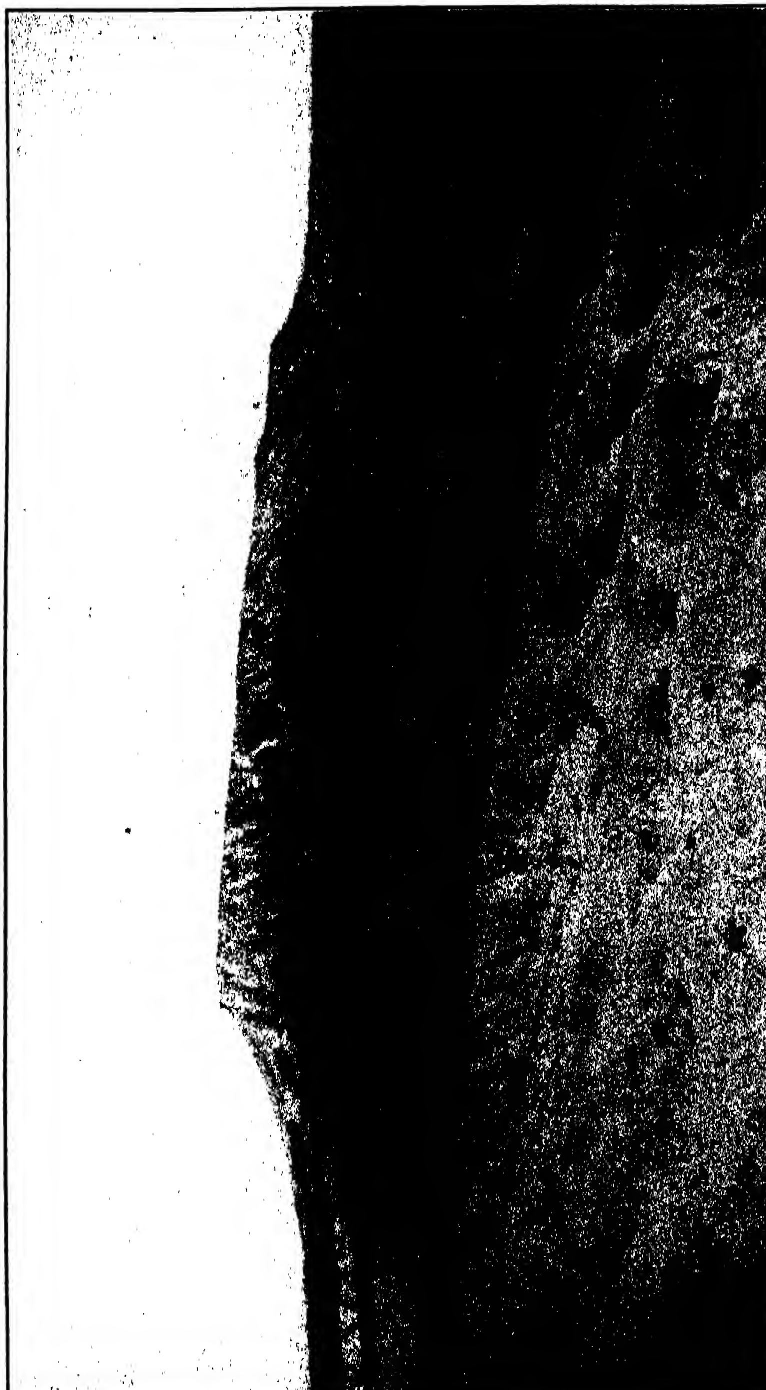
The White River Badlands, or the *Mauvaises Terres* of the early French-Canadian trappers, lie to the south of the Black Hills, extending into Wyoming on the west and thence east through Sioux, Dawes and Sheridan Counties in Nebraska. To this region the name "Badlands" has applied, not because the country is without economic value, for its grassy stretches support many ranches, but because of the difficulty experienced by early travelers in traversing its labyrinthine gullies and unassailable slopes. Water, too, in much of the region is alkaline and unfit for drinking purposes.

The intricacy of the erosion pattern is an ever-perplexing fact. Tortuous channels, usually dry, wind their serpentine course between steep ridges, and gullies heading in all directions add to the confusion of the landscape, a picture without vegetation save on the undissected



TORTUOUS CHANNELS

WIND THEIR SERPENTINE COURSE BETWEEN STEEP RIDGES.



YEAR BY YEAR THE BADLANDS CUT INTO THE GRASSLAND

flats, where each rainfall leaves its scar on the bare, varicolored walls of the non-resistant clay. To the south Pine Ridge marks the horizon with its pine and cedar-covered slopes, and far to the north in the blue gray distance loom the Black Hills. Between are the Badlands.

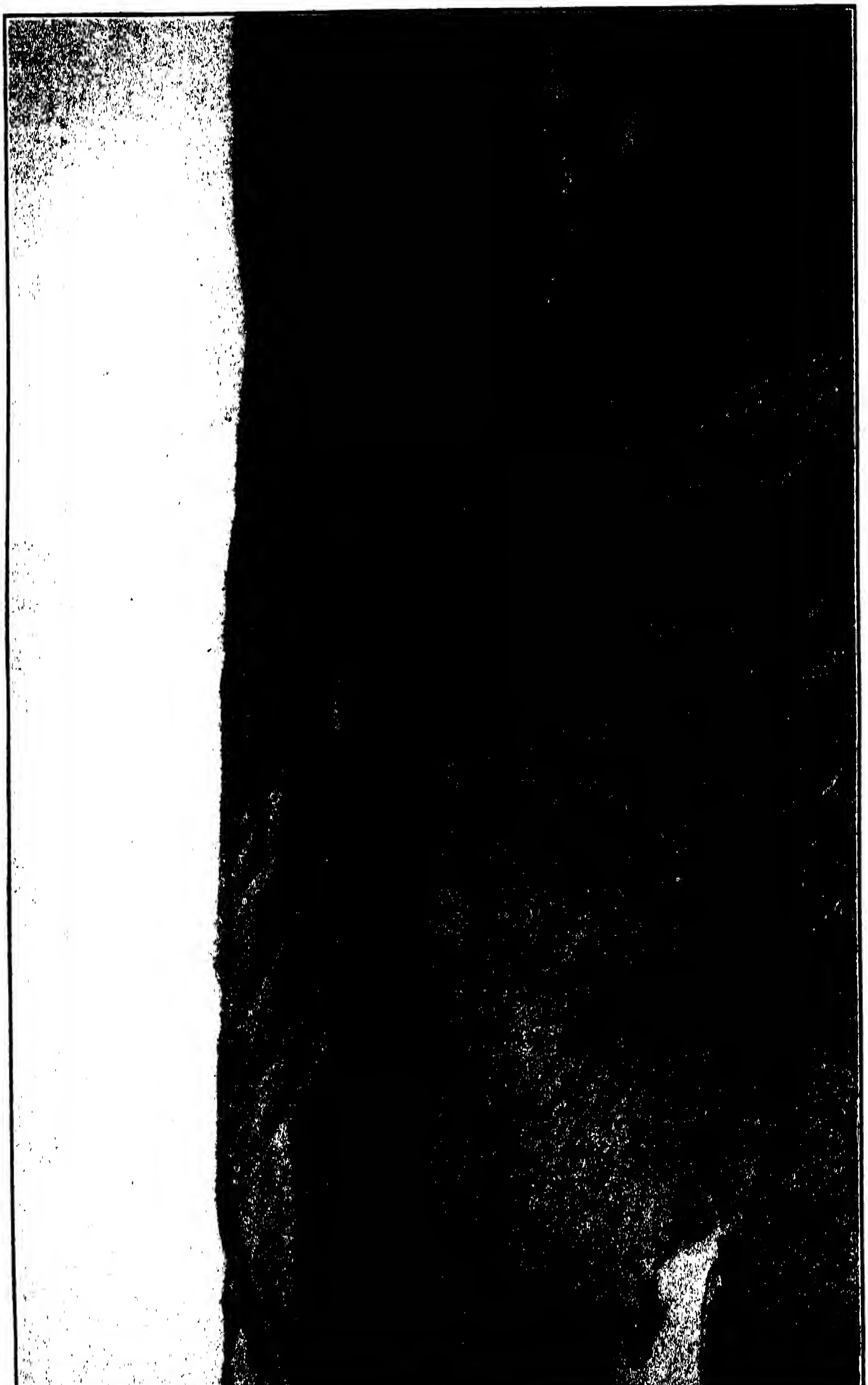
Within the barren area conditions are most favorable for the fossil hunter. The absence of masking vegetation renders visible each bit of bone as it was exposed by the last rain. Here is the ever-present *Oreodon*, a beast combining the characters of camel, deer and pig, and occasionally a fragment of *Dinictis*, the first of the saber-tooth tigers. *Titanotherium*, the giant of the times, roamed the plains during the Oligocene and their ponderous skulls are brought to the surface by the unceasing excavation of running water. It is the occasional rain and the melting snows which make it possible to collect a new crop of bones from the same area every decade, for the fossil hunter only digs where a bit of bone shows at the surface and passes over what he can not see.

As with other sports, fossil hunting has its own technique, but, unlike many, a fair degree of facility comes with the first few days of practice.

Comfortably established near a ranch house with our tent set up in one of the rare groves of trees, our first chase began in the cool of the early morning. I was a novice at the sport, having passed my first few years of fossil hunting in a country of early Paleozoic rocks which were deposited when the fishes were the only vertebrates, long before the beginnings of mammalian life upon the earth. Miller, however, was a veteran. His early years he had spent with the American Museum of Natural History, collecting dinosaurs at Bone Cabin quarry in Wyoming, a classic hunting ground so named because a shepherd's cabin whose walls were built of massive dinosaur vertebrae first attracted the attention of paleontologists to the wealth of fossil material in the surrounding slopes; he had searched the Bridger Basin in Wyoming for remains of Eocene primates, and for many years he had roamed the hillsides of northwestern Texas in company with the late Dr. Samuel W. Williston in quest of the Permian fossils which have made Walker Museum the repository of the richest collection of early amphibians and reptiles in the world. With such tutelage, the fundamentals of fossil hunting were easily mastered.

The ranch at which we were camped nestled under the protection of Pine Ridge and was enclosed upon three sides by the Badlands. Our first morning's sport was characteristic of many days to follow. With pack sacks slung over our shoulders and picks in hand, we wandered through the maze of gullies, stopping here and there to prod about a bit of bone peeking through the clay of the ravine wall. Usually the bone was a bit of rib, or a fragment of turtle shell, partly replaced by mineral matter from the percolation of ground water through the clay, but seldom was it replaced to the extent of being "petrified." A few blows with the pick sufficed to show that the fragment was useless, and we pushed on to where the next bit showed itself. So the morning passed.

It was late that afternoon when we made our first find. Miller had stopped to examine a patch of white, barely showing through the cover of greenish clay. I watched him prod about it with his trowel. Little by little he dug the clay away, and with each trowelful the whitish area increased. In a few minutes he had exposed enough to be able to tell me what he had found, the pelvis of a *Titanothere*, a mammal of almost elephantine proportions which disappeared from the earth long ages ago. When the last of the clay cover had been dug away, Miller brushed the bones clean and marked the spot with a piece of news-



THE CHADRON BADLANDS
IN THE FOREGROUND IS A TITANOTHERIUM PELVIS.

paper weighted down with a stone on the nearest ridge. Later, when we would begin our collecting, we could find our prospects by searching the ridges for markers.

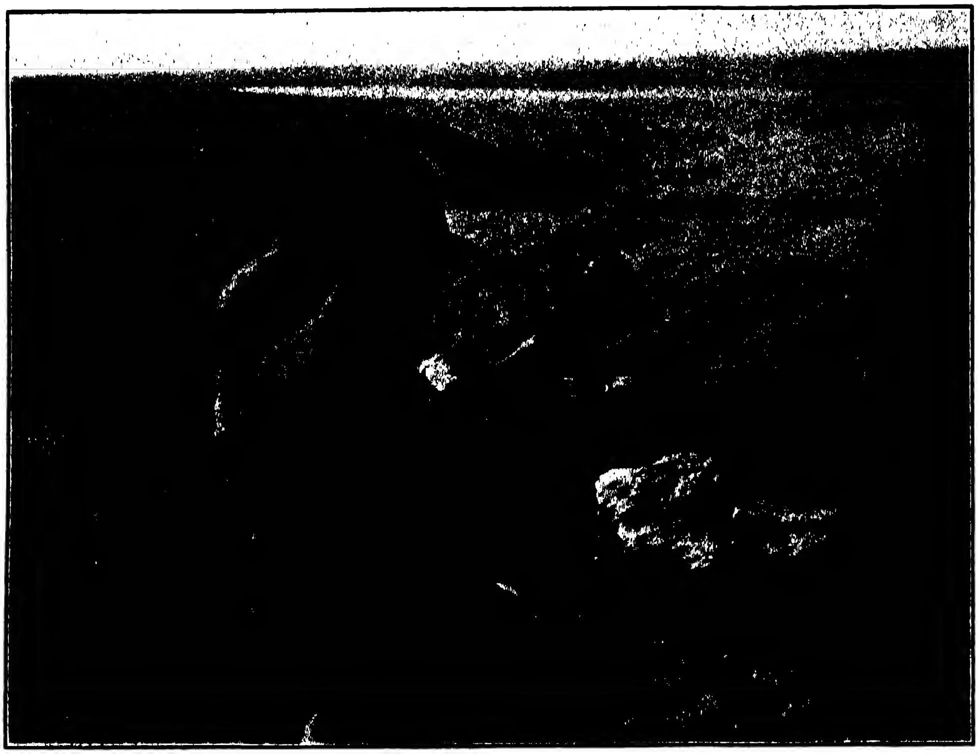
During the next few days our finds mounted apace. Miller had an uncanny knack for seeing each bit of bone and for recognizing those which were worth investigating, while I, at first, passed over bone after bone, only to have them brought to my attention with good-humored raillery over the blindness of the city-bred. Before the first week had passed, however, my observation was more acute, and, when early in the second week, I found our first skull of *Dinictis*, one of the early saber-tooth tigers, I preached my prowess as a fossil hunter from the hilltops.

By the middle of the second week, we had staked claim to several dozen skulls and a goodly assortment of skeletal remains of a great variety of beasts—*Leptomeryx*, the diminutive deer; *Mesohippus*, one of the three-toed horses, and *Hyracodon*, a member of the rhinoceros family. Then collecting began in earnest. Armed with a bucket of sour flour paste, thin shellac and strips of burlap, we sought the bones which we had previously marked.

Among our first finds was a *Titanothere* skull, a massive affair, the size and approximate shape of a Texas saddle. It was upright in the clay, with only the top exposed just as Miller had cleaned around it on our prospecting trip. The task ahead was to remove the skull from the ground without breaking it and to prepare it for safe shipment to the University of Chicago. First we carefully brushed away the clay to expose the outline of the bones, and then we dug a trench around it. As the trench deepened the clay fell away from the sides until the skull rested on a pedestal extending up from the bottom of the hole. The skull had been in the same position in the ground for several million years, all the organic matter which gives some degree of elasticity to fresh bone had rotted away ages ago, and the mineral material, somewhat replaced, was all that remained. Extending in all directions were innumerable cracks along which the skull would fracture, breaking into a hundred pieces, unless carefully prepared. In order to strengthen the bone material and to partly cement the cracks together, Miller applied several coats of very thin shellac which dried at once. Then overlapping strips of burlap which had been dipped in sour flour paste were plastered over the top and sides of the skull. We visited other prospects near-by, and on returning to our *Titanothere* we found that the few hours' exposure to the intense Badlands sunshine had dried the pasted strips into a rigid shell. Our excavating had left the bone resting upon a pillar within a hole some three feet across. It was a matter of a few minutes, then, to cut through the supporting clay and to lift the skull to the ground, bottom or unpasted side up. A few coats of shellac, and more paste-saturated burlap completely encased our find, and after drying, it was ready to be transported to camp.

The size of the bone of the massive *Titanothere* made transportation a problem worthy of much cogitation. Our Ford truck could traverse roads which were legends rather than actualities, but it was incapable of scaling forty degree slopes, or straddling knife-like ridges. But as the pyramids were made by man power, so was our skull transported to the figurative road where we had left our truck.

Several days of shellacing and pasting followed, and then we again roamed the gully slopes in search of fresh finds. Often we separated in the morning, each hunting the hillsides for his ancient game, and at night, after clearing up our supper dishes we exchanged our day's adventure. Most evenings we returned



ANOTHER TITANOTHERIUM SKULL

with pockets loaded with teeth, portions of jaws of the little water deer and odd vertebrae. And as we swapped stories we spread out the day's finds in corroboration. One evening Miller came in later than usual. I had returned to camp an hour before sundown with a young cottontail which was soon sizzling merrily in the frying pan. Now Miller is one of the most appreciative men that I know in the matters of culinary import, so when he passed my frying pan without comment, and began to empty his pockets I suspected that something of unusual interest had found its way into his day's acquisitions. At last, from the bottom of his bag he pulled out an egg. It was not a contemporary egg, or even one of those old ones of unpleasant repute, but it harkened back to the days when our Badlands were grassy plains with pleasant streams and shady lakes. What manner of bird had laid it will in all probability remain shrouded in uncertainty, but the egg, the size and shape of its barnyard successor, had withstood the load of sediments piled upon it, and, following petrifaction, had come to light some three million years after its deposition in the nest.

Upon one of our rambles, when we had strayed far from the home ranch, we climbed out of a gully which headed by the stoop of a little cabin. It was a shrinking sort of home, unthatched and weatherbeaten, the home of two bachelors and their maiden sister, all well past middle age, who found life's necessities in an unceasing struggle to make their little ranch support a diminishing herd. It was a disheartening struggle, for year by year the Badlands had drawn closer

about their acres and cut deeper and deeper into their insufficient pasture land. So much we heard later.

As we emerged from the gulley, at its very head, within a few yards of the doorway, Miller dropped to his knees and began to dig in the manner that I had come to recognize as indicative of an unusual find. A few well-placed prods with his awl confirmed his surmise—here, just showing through the clay, was a cat skull, arches intact, the jaw in place—a gem which would well reward a field season's searching.

We had barely begun our preparations for collecting our find when the elder rancher joined us. He was courteously firm in his refusal to permit us to collect the skull; to do so, he explained, would be in defiance of scriptural teaching. These bones were man's proof of the Mosaic flood, evidence that could not be disputed, and their removal could only be interpreted as an unethical and unchristian attempt to destroy the evidence of the flood in order that such heretics as we would no longer be confronted by material proof of the literal exactness of the Old Testament. So much he gave in explanation of our ejection from his property. We retreated with as much dignity as the situation permitted, scoffing a bit at the old man's argument, but impressed by and respecting the sincerity and conviction of his beliefs.

I tell what followed with a least bit of shame, not at our success in securing the skull, but at the way in which we secured it.

We spent the next two days watching the cabin from a neighboring hill, and at last saw the three old people climb into

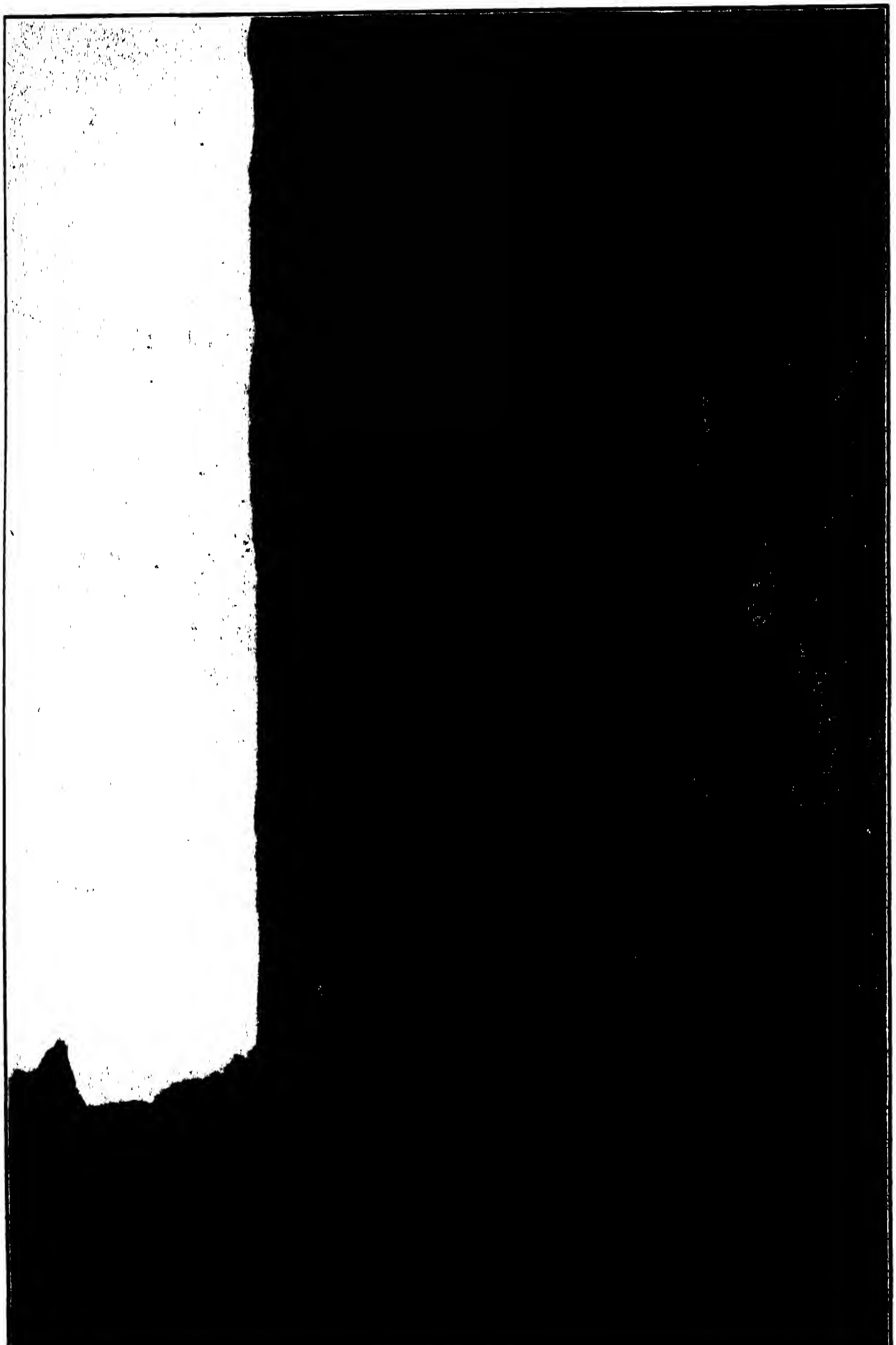
MILLER COLLECTING A FOSSIL TURTLE

COLLECTING A RODENT SKELETON

the buckboard and disappear into the canyon on the road to town. Two hours later the cat skull was in Miller's bag and we were exercising our paleontological technique in planting the skull of an *Oreodon,* a dozen of which could be found in an ordinary morning's collecting, in the exact position, a hundred feet from the cabin door, from which we had plundered the first skull. That the cat should have been collected for the university does not seem to me to be worth debating; that we resorted to stealth to take it seems justifiable under the circumstances; but that we should have deliberately planted an *Oreòdon* in its place is an act for which I have many times since felt just a bit ashamed of myself. But, after all, the old people will never know the villanies to which fossil hunters will descend.

One of our best skulls was acquired through barter, a carton of cigarettes for a perfect skull of one of the giant pigs. Some one at Harrison told me of a skull about two feet long that had been found by a ranch hand in Hat Creek Basin. Without consulting Miller, I rode out to see what manner of beast the cow-hand had found. The ranch seemed to be deserted as I rode up—a few horses moved restlessly in the corral, but there was no sign of human activity. At one side of the porch, propped against the house wall, was the skull that had brought me from Harrison. It was not as large as rumor had made it, but its perfection was beyond anything that we had so far come across. Long snout with tusks, cranium complete, both arches present —it was a thing of beauty. Now I consider myself possessed with normal respect for the eighth commandment. Under ordinary circumstances I would re-

AT NIGHT WE SMOKED AND SWAPPED STORIES



EXCAVATING IN THE AGATE SPRINGS FOSSIL QUARRY

gard theft with reprehension. At that moment, however, I had considered the probability that the rancher might not see fit to allow me to take the skull away, and I was walking out of the gate with the prize under my arm. Then I met the rancher. My explanation—I've forgotten what it was—was probably a bit weak, but in a country where doors are never locked, honesty is assumed in all men. I admired the skull. I praised it. I might even have rhapsodized over it, but my best enthusiasm failed to suggest to him that his gracious gesture would have been to have presented me with it. Finally I asked him for it. He was unresponsive. It seemed that he valued that particular skull as the biggest that he had ever found. Folks came to see it, and in sparsely peopled countries that which draws visitors is prized by all men. Flatly, he refused to part with it.

To hide my disappointment in a graceful manner, I lit a cigarette, and being resentful I did not offer one to him. As we talked crops and weather by way of parting I began to recognize delicate suggestions that a cigarette would be appreciated. Being still resentful I ignored the hint. At last he confessed being out of tobacco, and being unable to drive to town that day. That was my chance.

I said, "There is a carton of cigarettes in my bag. You have a skull. Let's swap." We swapped, and the skull, duly mounted, reposes in a case in Walker Museum.

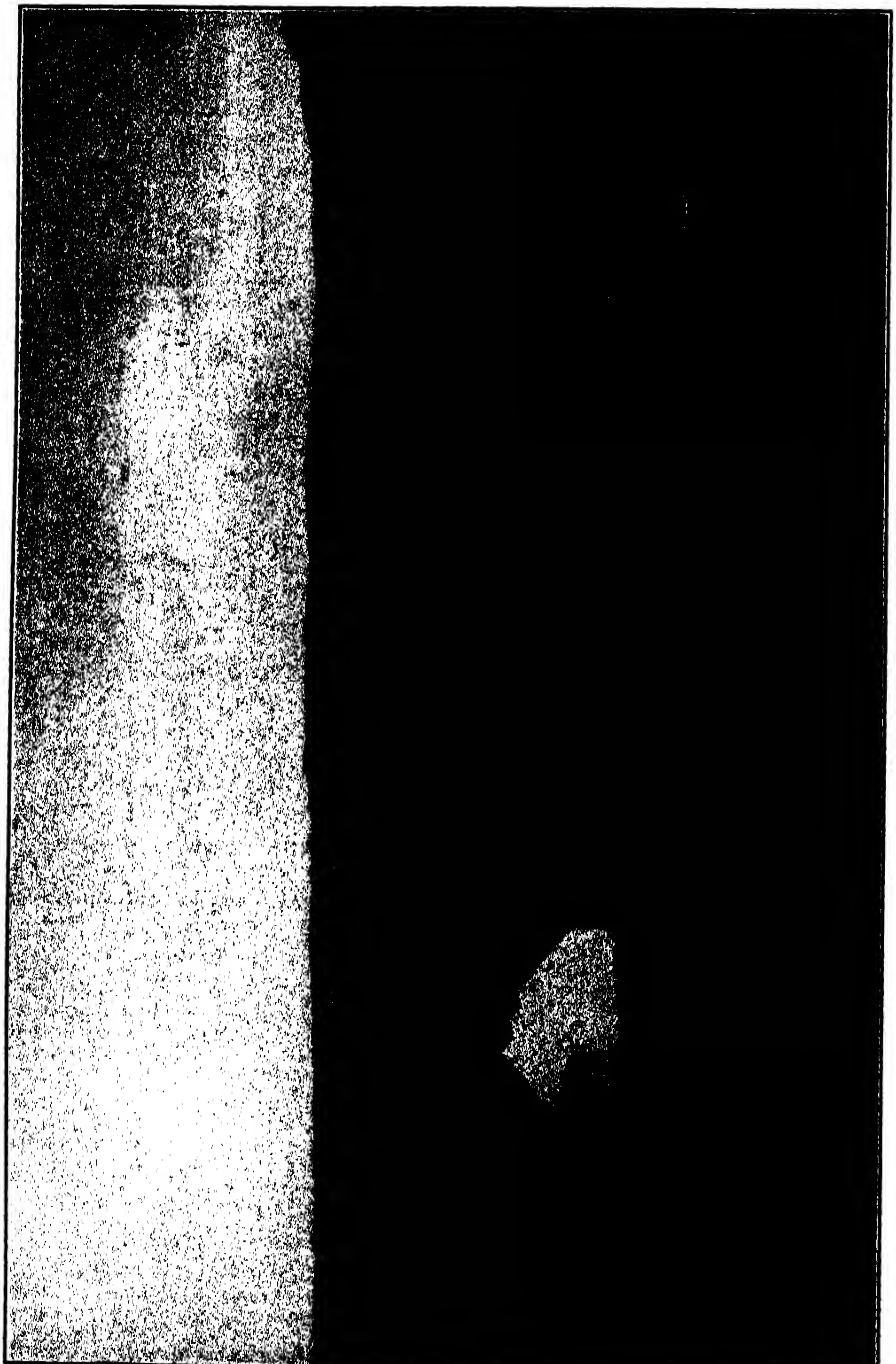
At the end of five weeks the time when the funds which the university had appropriated for our expedition would be exhausted was uncomfortably near. We had accumulated a half ton of fossil bones, representing a score of animal species, all carefully boxed for the journey to Chicago. Our finds had been assembled in our camp at the foot of Pine Ridge, eighteen miles away and several hundred feet below the railway at Harrison upon the upland to the south. The road to town threaded its precarious course up a miniature canyon, continually recrossing the stream bed. We had found on our trip to town for provisions that the rapidly ascending road could not be taken in "high." We had also found that three canteens of water administered periodically to the radiator of our truck would prevent our being mistaken for a traveling geyser.

There followed two days of hard labor. Our truck, loaded to capacity with boxes and crates of bones, crawled up the canyon trail to the freight depot, discharged its cargo and returned for more.

It was with a feeling of relief from oppressive responsibility that we watched our precious bones being loaded into the freight car. The boxes might be torn board from board on the trip home, but it would be the will of Allah and beyond our help.

There remained a visit to the ranch of Captain James Cook and his Agate Springs fossil quarry. Perhaps pilgrimage would better express the spirit in which we drove south from Harrison, for Captain Cook was the beloved friend of fossil hunters throughout the country.

Miller told me about the Agate Springs quarry as we drove along—how the captain's son, Harold J. Cook, had homesteaded the fossil hill in order that the museums and universities of the world might be free to collect its treasures and that no single institution could control their distribution. How Captain Cook, after an adventurous youth in which ranching and Indian fighting alternated, settled at the headwaters of the Niobrara River, in Sioux County, Nebraska, and became the respected friend and trusted adviser of Red Cloud and his chiefs. How his counsel preserved peace between the Sioux and the early settlers, and how in his maturity his unfailing interest in the world about him had led to the discovery of the Agate Springs fossil quarry. Miller



HAROLD COOK'S HOMESTEAD CABIN,
NOW THE CAMP OF THE AMERICAN MUSEUM OF NATURAL HISTORY.

told of Captain Cook's friendship with Professor O. C. Marsh, of Yale, one of America's great students of ancient mammalian life, and later with Barbour, Osborn and Matthew. It was a story of the keenest fascination, and I again experienced the joy of the adventure as I read Captain Cook's autobiography.[1]

With the exception of the scrub conifers upon Pine Ridge we had not seen a tree for over a month. I was not prepared for the park spread out below us as we stopped at the edges of the valley which the Niobrara River had cut in the undulating uplands. For miles we had been driving through a sage-green landscape in which dryness was the dominant note, and then, at the descent to the river, we saw trees, scores of them, and in the center of the grove the homiest of ranch houses. Years ago Captain Cook had planted the grove, and with unceasing love he had watered it; indeed a miniature irrigation system brought moisture to the roots of every tree, and now, in justification of the care lavished upon it, here was a paradise in the desert.

We crossed the bridge and drew up before the ranch house. It was not Miller's first visit, for in years past collecting had brought him to Agate Springs. Captain Cook greeted us with the hospitality traditional of the west, but which is retreating even there before industry's smug self-sufficiency. We were shown over the grounds and came to rest in Harold Cook's museum and workshop. He, the captain's son, was a boy when the early fossil discoveries were made. His imagination, fired by the relics of ancient life which the rocks yielded, spurred him to seek knowledge of that early life and when, in later years, after his studies at the University of Nebraska and at Columbia, he returned to the business of ranching his researches in the local paleontology yielded a museum of more than passing interest.

[1] "Fifty Years on the Old Frontier," by James H. Cook: Yale University Press, 1923.

Toward evening we pushed on to the quarry, paralleling the Niobrara for two or three miles. Other fossil hunters were in camp. Dr. Matthew and Mr. Thomson, of the American Museum of Natural History, occupied the old homestead cabin and camped nearby were parties from the universities of Michigan and Kansas. Community of interests is the best formula for fellowship, for in our brother collectors we found countless stories of fossil hunting in the early days of the Cope-Marsh rivalry, when Indians still considered the skin of a "bug-hunter" just as white as that of a pioneer.

Our moments of keenest enjoyment come unbidden and unplanned. Such times of unalloyed contentment, when we forget the humdrum monotony of everyday life and are keyed to the reception of all that is exotic and unreal, when the glamor of adventure cloaks the unadventurous and we ride roughshod over our inhibitions of rationality are never consciously induced, but are always byproducts of one's surroundings, coming at the unexpected moment and vanishing at the recognition of the mood. Later, I realized that as we sat about the fire listening to yarns of fossil collecting at the far corners of the earth I had slipped into that realm of enviable irrationality, where the stories of mild adventure donned a glamor which can never be set down. It was early morning before the last reminiscences were over, and I had drifted back into the everyday. Indeed I must have retained a residual vision of that fantastic kingdom into which I had strayed, for dreams of curious creatures of extramundane aspect appeared during the remaining hours of darkness.

Morning brought back the familiar world. Three conical hills stood out

upon the valley flat. That nearest us, University Hill, contained the long heralded Agate Springs fossil quarry. After breakfast we ascended the slope to the quarry where the parties from the universities of Michigan and Kansas were already at work, removing great blocks from the floor, for here the fossil remains were in such numbers that their removal from the rock could best be done in the home laboratory. How such a jumbling of skeletons of the rhinoceros, *Diceratherium,* could have occurred is one of nature's jealously guarded secrets. If one imagines a swirling river rushing across a grass-covered plain, and then, in his mind's eye, watches a great rhinoceros herd struggling to ford its treacherous bed, sees them falling one by one in the struggle to breast the current, and swept away into an eddy down the stream, there to swirl around and around until the meat has rotted from the bones, and skeleton after skeleton has dropped to the river's bed, he has as adequate a conception of the secret of the great bone accumulation as have the paleontologists who unearthed the storehouse.

I remembered a slab from the quarry floor which Miller had collected in a previous year. He had removed a block some three by five feet in size by cutting a channel around it and then undercutting the boarded up slab. In his laboratory he had chiseled away the sandstone, leaving the bones which he exposed standing in relief against the matrix. They were jumbled as though a dozen disarticulate skeletons had been heaped together—skulls, vertebrae and digits, and then the whole mass imbedded in sandstone plaster.

Two such slabs were in the process of being removed as we reached the quarry. I wanted a picture of the collectors at work, and so I climbed to a nearby hillock and set up my tripod. Just as I had thrown the focusing cloth over my head I heard a sound which had become familiar in my weeks in the Badlands. It was akin to the noise which some katydids make by scraping their spike-studded jumping legs against the wing coverts, and yet it was not a katydid. Soon a similar sound reinforced the first. By that time I was several jumps away from the spot and calling over to the quarry for a pick. When the stone on which my tripod rested was turned over, two very angry rattlesnakes hurled defiance to an unfriendly audience. As the American Museum party was collecting for shipment to the Bronx menagerie such rattlesnakes as were incidental to the business of bone-hunting, we succeeded in roping the rattlers with a noose, and with Miller at one end of the rope, I very uncomfortably at the other, and the two snakes dangling in the middle, our procession descended upon the cabin where the new captives joined some half dozen of their fellows in a sugar barrel.

The day following found our truck stored at Harrison for the next field season, and Miller and me uncomfortable in the habiliments prescribed for traveling. We were going to different parts of the country, and as Miller's train began to move he called back to me, "Bill, you almost made a paleontologist."

RADIO TALKS ON SCIENCE[1]

WINTER'S MUSIC

By Dr. W. J. HUMPHREYS

THE U. S. WEATHER BUREAU, WASHINGTON, D. C.

The Song of the Four-Horse Wagon

Did you ever hear the happy, cheery song of the four-horse wagon? If you ever did, you have not forgotten it, and you never will. When the air is still and very cold, the creak and cry of the crumbling snow and the high-pitched notes of the passing wheels make sweet music that in later life arouses the fondest memories of home and childhood days.

As children we were not always content just to listen and wonder, however sweet the sounds, but sometimes asked our elders: "What makes the wagon sing?" If they told us the snow did it, we, child-like and scientist-like, asked how. Then the subject was changed, and few of us to this day know how the snow makes the wagon sing.

It doesn't always sing. When the temperature is only a little below freezing the snow merely packs to streaks of ice and the rolling wheels are dumb. They find their voices, high-pitched and clear as a bell, only when it is so cold that the snow will not cohere, and their course therefore is no longer marked by ribbons of ice, but by paths of crumbled and powdered crystals. This, then, is the key to the explanation we want. When the conditions are just right for the fine old sport of snowballing the crystals partially melt under the pressure of the wheels and flow together without slip or jar, just as they mould to balls under the squeeze of the hands, only to refreeze, now in a united mass, as the wagon passes on and its weight is removed. When, however, the snow is very cold, it does not melt but snaps and breaks like glass beneath the steel tires of the passing wheels. Every break, every sudden slip and readjustment of the crunching snow not only jars the air directly, as it does under our boots, but also indirectly through the simultaneous and consequent tremors of the wheels and other parts of the wagon. But here our knowledge, at any rate my knowledge, of this fine example of winter's music abruptly ends. Does the snow play only the part of the rosin in the case of the fiddle and the bow, imparting different notes to different wheels, but always the same note to any given wheel whatever its speed or load? Or, on the other hand, do big wheels and little wheels, heavy wheels and light wheels, all sing the same note, a note dependent on some inherent property of the snow and nothing else? What an opportunity is here for a whole series of most interesting investigations!

The Hum of the Telegraph Wire

Another question many a bright child asks without, as a rule, getting a satisfactory answer is: "What makes the wires hum?" If you tell him, and truthfully, that it is the wind, he comes back at once with his favorite poser, "Why?" And in this case a poser it surely is, if we may judge from the variety of silly answers that seriously have been given to it. However, experiment has gone a long way, though not yet all the way, towards furnishing the correct answer.

[1] Broadcast from Station WCAP, Washington, D. C., under the auspices of the National Research Council and Science Service and the direction of Mr. W. E. Tisdale.

If we fasten a light strip of cloth to the side of a slender pole when a stiff breeze is blowing, we will see that it does not stand out straight and quiet, but waves and flutters. And the same thing occurs, as long as we can follow up the experiment, with change of diameter of rod and size of flag. Finally, smoke particles show that even the passing stream of air itself flutters in the same general manner, with a frequency that increases with the strength of the wind and with decrease in diameter of the obstructing rod. There is, then, a fluttering eddy of air attached to every wire exposed to the wind—a fluttering generally fast enough in even very moderate winds, to make a musical note. This fluttering, in turn, produces slight variations of the same period in the pull on the wire, hence in the tug on the supporting poles, which therefore become sounding boards, increasing the volume but not the pitch of the hum. Of course telegraph wires, and others too, sing in all seasons, but as they sing loudest when the wind is brisk and transmit stronger tugs on the poles when tightly stretched, as they are when contracted by cold, their song too is, in the main, a joy of frosty weather.

It would be pertinent to ask here why the stream of air around a wire in a wind flutters so regularly as to create a musical sound, or, indeed, flutters at all, but the answer to that question even in its present imperfect stage, can only be given in pages of mathematical equations—the most concise, as written, and elegant of all languages, but wholly unspeakable.

The Dirge of the Lone Pine Tree

When the mood is right, and no one near to distract, there is a peculiar pleasure in listening, on a windy winter night, to the dirge of a lone pine tree, as it ceaselessly wails in deepest sympathy for whatever loss your own memory may recall or fancy suggest. But when the spell is broken you may ask yourself, "How does the old pine tree get its sighing and wailing voice?" The answer now is easy. Every one of its myriad needles produces a little vibrating eddy in the wind that blows across it, just as the telegraph wire does, and this vibration is fast enough to make a musical tone. The voice of a single needle usually is faint beyond the perception of the most delicate ear, but just as a swarm of bees produces a great buzzing noise where the individual bee could not be heard, so too the voices of a million pine needles blend into a loudly wailing dirge.

Other trees have voices too, mere rustles in the summer when their leaves are on, but coarse and indistinct mumbles in the winter time, caused by the eddying winds about their twigs—a coarser and less distinct voice than that of the pine, because the twigs are larger than the needles and more irregular in size. Nevertheless, the winter murmur of a forest of trees of any kind, as the wind rushes through them, is a pleasant sound to hear, unless indeed we fear too much the coming storm such murmur often foretells.

The Howling of the Wind

One of the greatest pleasures of a wild winter's night is listening to the howling of the wind as it sweeps past the chimneys and over the gables. Most of us are content just to let it howl—to "take the good the gods provide," and ask no questions, but a few are curious to know how the blustering wind gets all its voices, or, indeed, any voice, but our curiosity has never been fully satisfied. We have only learned that here, too, the sounds are caused by an endless succession of eddies produced in the wind by the obstacles over which it is blowing; but the whole story we do not yet know.

Booming of Lakes

In any cold lake region a familiar winter sound is the occasional boom heard far and near as, under the strain induced by a great difference in temperature between its upper and under surfaces, and in other ways, a thick sheet of ice snaps and tears in long cracks and rifts.

The Bursting of Trees

During an intensely cold wave one may hear in a forest an occasional "pistol shot" where there is no pistol, and none to shoot it. It is only the outer shell of a tree splitting under the great strain caused by its cooling faster and therefore shrinking faster than the inner wood. This is not a frequent note in the winter's music, but it may be very impressive, or, indeed, startling, if one happens to hear it while alone in a forest on a dark night.

The Cracking of Joists and Rafters

A good thing to keep one awake in the wee hours of a bitterly cold night is the snap, snap, bang, of the joists, rafters and other portions of an exposed country house, as the tug of the cold jerks their joints into new adjustments. We listen for the next bang, wondering when it will come, then the next, and the next —sometimes enjoying it, but more often, perhaps, wishing we could go to sleep.

The Rattle of the Sleet

When the temperature is only a few degrees below freezing, and a storm is gathering, there occasionally comes a faint tick on the window, as of a grain of rice thrown against it, followed soon by another, and that by still others, faster and faster, until there is a continuous rattle, varying in volume with every gust and eddy of the wind. This is the rattle of the sleet, a sound peculiar, of course, to the winter, and disagreeable or pleasant owing, partly, to whether we have to go out in the storm, or may stay indoors, snug and dry, where the artificial weather is gentle and balmy.

The pth, pth, of the Glowing Fire

When a big wood fire, one of the finest pleasures of a winter in the country, is well burned down and there is a great bed of glowing coals in the ashes, we often hear a muffled popping, pth, pth, somewhere in the fire, but exactly where we can not be sure. On such occasions our grand-dads used to say: "It is going to snow," and very often they were right, because on so raw a day as that which usually just precedes a snow one is apt to have a good big fire. Some said: "The fire is spitting snow." Others, more elegantly, but less accurately descriptive, said: "The fire is treading snow."

These faint but fascinating sounds are, apparently, owing to little explosions of combustible gases coming up from hot bits of wood, charcoal and glowing embers more or less buried in the ashes.

There are, of course, various other interesting bits of winter's music, but we well may end with the pth, pth, of the fire, since it so often is heard as the evening is wearing on and the last fire of the day is dying down. Indeed in a very real sense it is winter's lullaby, or goodnight song, for under its spell we do grow drowsy and nod.

OTHER UNIVERSES

By JAMES STOKLEY
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WE do not know when man first began to study the stars, but among the records of many early peoples we find that astronomy had already become a well-developed science. To the ancient Greek philosophers the relation of the earth and the celestial bodies that they saw in the heavens was a major problem. One hypothesis, attributed to Eudoxus, who lived in the fourth century, B.C., held sway for over fifteen hundred years. Known as the Ptolemaic theory, after Ptolemy, the Egyptian astronomer who wrote of it in his great work, the "Almagest," this stated that the earth was at the center of the universe and that the planets and fixed stars revolved around it.

But, long as it held, man and the earth were finally deposed from this important position and the Ptolemaic theory was superseded by that of Copernicus, which placed the sun at the center and made the earth but one of a family of planets that revolve around it. However, so far as Copernicus was concerned, the sun was actually the center of the universe and the stars were fixed on an infinitely distant sphere. With the invention of the telescope, in 1610, and its use in observing the stars, first by Galileo, and then by many others, it became apparent that the sun was a star, and, conversely, that the stars we see in the night sky were suns, but so far away that they appear as mere points of light. It is difficult to comprehend the distances of these orbs, so suppose I were to make a model to scale. In my hand I have a ball an inch in diameter representing the sun; a dot a hundredth of an inch in diameter and nine feet away represents the earth, but Alpha Centauri, the nearest star, is in Columbus, Ohio, 330 miles from Washington! Actually the sun is 865,000 miles in diameter, and the stars are so far away that astronomers can not use miles to express their distances. Instead, they employ the "light year," equal to about six trillion miles, or the distance that a beam of light, travelling 186,000 miles in a second, as fast as the radio waves that carry my voice to you, would go in a year. Alpha Centauri is a little over four light years away, Sirius, the Dog Star, about seven and a half, while the distances of most of the stars are measured in hundreds, or even thousands, of light years.

Distant as the sun's neighbors are, with it they form a system, or universe, of stars, which, as the English astronomer, Sir William Herschel, showed about a century ago, is approximately the shape of a watch or a grindstone. The sun is not far from the center and as we look towards the edge of the grindstone we see such a vast swarm of stars so closely packed together that to the unaided eye they appear as a continuous area of light, which we call the "Milky Way," but in other directions the stars are not so numerous. Even a small telescope reveals the individual stars in the Milky Way, while with a larger glass we see that some are double, that is, instead of consisting of a single body, there are two, which revolve around each other. Still others, which to the naked eye, or with a small telescope, may appear single, are really multiple, consisting of three or more separate bodies.

In addition to these, with a moderate-sized telescope, we may see some star clusters, groups of thousands of stars, some irregular and some of a globular shape. In a small telescope, or under

poor conditions with a large one, these clusters look like continuous areas of light, similar to the Milky Way when seen with the unaided eye. Herschel, who had the largest telescope built in his day, saw the constituent stars for the first time in some of these clusters, so when he saw other nebulous objects that could not be separated with even his highest powers, he concluded that they too were made of swarms of stars that might be seen with a still more powerful instrument. Some, he suggested, might be actual "island universes," similar to our grindstone-shaped cluster and far beyond its limits.

But about 1860, astronomers began to make use of a powerful new tool, the spectroscope, by which it was possible to separate the star light into a rainbow-like spectrum, crossed by numerous dark lines, which, to those who can read them, reveal the composition of the star. Principally in the hands of another English astronomer, Sir William Huggins, the spectroscope was applied to the study of the nebulae, and most of them proved to consist of glowing gases. Such nebulae, then, were actually the irregular clouds of light that they appeared to be, but there are others that display a definite spiral structure, something like a Fourth of July pinwheel in appearance. Only one of these is bright enough to be seen by the unaided eye as even a faint spot of light under the best conditions, but it has been estimated that at least 700,000 are within the grasp of modern telescopes. When looked at, even through the great 100-inch reflecting telescope at the Mt. Wilson Observatory, they are disappointing, but when photographed with an exposure of many hours, their light can "soak in" on the sensitive plate and their real form may be appreciated.

Some of the spirals are seen "head on," others at an angle, and still others display to us only their edges, for they too have the shape of a grindstone. All do not show the spiral structure equally well, but they can be arranged in an almost continuous series, depending on the perfection of their shape, which suggests that each might represent a different stage of development. But perhaps their most significant characteristic is that while the stars, clusters, gaseous nebulae and all the other celestial objects are vastly more numerous in the Milky Way than elsewhere in the sky, not a single spiral has ever been found in this luminous belt!

The spectroscope also tells something about them. Instead of showing a spectrum of bright bands of color like that of the gaseous nebulae, they give one resembling that of the stars, but not of any particular star. Rather is it like a composite spectrum that might be obtained from a large mass of stars closely packed together. This fact, combined with those of their shape and distribution, seemed to furnish a clue to their nature. Might they not be actual island universes, like our own, and outside its limits? This seemed reasonable, and was advocated by several eminent astronomers, but what was apparently important evidence against it was furnished by Dr. Adrian Van Maanen, of the Mt. Wilson Observatory.

The spiral arms of some of these nebulae are not entirely continuous, but show knots, or condensations, and by comparing photographs made twenty years previously by the 60-inch reflecting telescope of the observatory with others that he made of the same objects a few years ago, he found that apparently the material of which the nebulae consist was moving outwards along the arms, at a speed to take it completely around in a quarter of a million years. While such a speed might seem slow, it would actually be exceedingly fast, for if the nebula was one hundred light years across, which would be far smaller than our universe, and scarcely more than the distance of some of the

nearest stars from the sun, the material going around it in a quarter of a million years would have to travel nearly a million miles an hour! If the nebulae were far enough away, and sufficiently large, to be actual island universes, the speed would have to be impossibly great for any material substance, so this seemed to be the death blow of the island universe theory.

But sometimes scientific theories have a habit of coming to life after they have been killed and buried. During the past year Dr. Edwin P. Hubble, of the Mt. Wilson Observatory, announced that he had discovered in several of the spirals a number of Cepheid variable stars. These periodically become bright and then faint again, but unlike other kinds of variable stars, the greater their average brightness, the more rapidly do they vary. Their apparent brightness at any time may be measured by the astronomer from the strength of their images on his photographs, the period of their variations may be found by comparing plates made at different times, and this gives their actual brightness. We know how rapidly light diminishes as it passes through space and so the ratio of the actual and apparent brightnesses enables us to calculate their distances. Suppose you see a light so many feet from you. If you know how far it is you can estimate its actual brilliancy, but also, if you have in some other way found out how bright it really is, then you can estimate its distance.

Using this method Dr. Hubble found that some of the brightest, and presumably the nearest, of the spirals are at a distance of about a million light years! This places them definitely outside our system, which, though estimates of its size vary, is hardly more than three hundred thousand light years across. But to clinch his argument, Dr. Hubble photographed two of the spirals with the highest powers of the 100-inch telescope at Mt. Wilson, and actually showed parts of them as hordes of faint stars, proving them to be actual island universes, just as Herschel suggested so many years ago! Recently I had the pleasure of visiting Dr. Hubble at Pasadena, and he showed me his original plates, some of which he made last summer, and he told me how, by means entirely independent of the Cepheid variables, he had remeasured the distances and found them entirely in agreement with his previous work. Columbus discovered half a known world, but how much greater is this man, who has discovered a host of new universes?

But, you ask, what happens to Van Maanen's work, and how can it be reconciled with the new discoveries? These questions are being asked by many astronomers, particularly Drs. Van Maanen and Hubble themselves. As Dr. Van Maanen is recognized as a skilful observer, no one questions the accuracy of his results, but the effect may not be a real one. For instance, in some of the spirals spectroscopic evidence indicates that the arms are closing inwards, instead of opening outwards. In 1918, a new star flashed out in the constellation of the Eagle, and a series of photographs of it showed what was apparently matter moving out from it with a speed comparable with that of light itself. This was shown to be, not the actual motion of matter, but the front of the wave of light from the star as it burst out from its previous obscurity. It had been surrounded by clouds of cosmic "dust," dark matter previously invisible, but as parts of this dust cloud farther and farther from the star became illuminated, we saw what was apparently a rapidly expanding cloud. Perhaps something similar is occurring in the nebulae.

In any event, we can not but feel all the more the minuteness of man in the great Cosmos. From an earth at the

center of everything according to his former ideas, his home became but one of a number of planets revolving around the sun, his sun became but one of many stars, and now his system of stars turns out to be but one of countless hordes of universes! Is this the last step? Who can tell?

WHY THE SEA IS SALT

By G. W. LITTLEHALES
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THE approach to the discussion of the subject, "Why the Sea is Salt," is to be sought in considerations respecting the origin of the earth. The penetration of mathematical astronomy and geophysics into the origin of the earth has resulted in ranging the oceanographer in the ranks of those who have maintained that surface geology, like volcanic, does not demand the excessive temperatures which would have necessarily attended the formation of this planet by the gaseous-molten process of the nebular hypothesis. The oceanographer's position in this respect is prompted by the necessity which confronts him of accounting for an ocean of the volume of that which actually exists on the earth.

Spread over more than two thirds of the surface and yet amounting to but little more than one one thousandth part of the whole volume of the globe, the ocean, with its average depth of two miles, is represented by a sheet of water of a thickness of only one four thousandth part of the diameter of the earth. It is not without importance to point to the analogy that this depth is no greater than the thickness of the film of water that would cling by capillary attraction to a rubber ball of four inches in diameter, being on that scale only one one thousandth part of an inch. From a sphere of this size composed of suitable material such a film could easily be exuded.

By the nebular or gaseous-molten hypothesis, the original earth-nebula contained the materials of the present ocean and atmosphere. When the solid earth-body had cooled sufficiently, condensation of the water of the primitive atmosphere would have taken place to form the ocean. But the indications are that by this process far more water would result than the world contains.

Probably, then, the ocean has not had its origin in the primitive atmosphere surrounding a hot earth-body slowly solidifying from a gaseous-molten phase.

As knowledge increases, old beliefs not only may lose their value, but may thwart progress. The spirit of critical inquiry is necessary.

> New occasions teach new duties;
> Time makes ancient good uncouth;
> They must upward still, and onward,
> Who would keep abreast of Truth.

It is by regarding the earth as having been evolved by planitesimal accretion around a nucleus condensed from a part of the material of an eruptive bolt from the sun that a more rational explanation of the origin of the ocean is reached. It is far more likely that it has come from the water chemically combined with and absorbed by the planitesimal dust. As this solidified and then became disintegrated, the water was liberated.

At first, when the earth was small, the water would escape as vapor into interstellar space on account of the deficiency in the intensity of the embryo earth's gravitational field to retain water vapor as an atmosphere. It is doubtful whether Mars, with a mass one tenth as great as that of the earth, can now do

so. But, grown to its present mass, it is even possible that the earth continually captures water molecules from outer space, and it is also probable that the water included in the last planitesimal accretions is still being exuded. On this view, then, the ocean is very slowly increasing in volume.

When first the ocean was chained captive at the wheels of the evolution of the earth in the basin that became the crucible in which was distilled the first living cell, its waters already contained saline constituents dissolved out from the planitesimal materials that cohered to form the nuclear-earth, and age-long accessions to the salts of the sea have been brought down to it by the rivers. But either the materials thus reaching the sea were different in the past from what they are now or else there have been processes at work that have made the composition of ocean salts different from river salts. At present the two dissolved mixtures are not the same. In the ocean, the relative abundance of chlorine, sulphur (asSO_4), and carbon (asCO_3) is in the order named and likewise is the relative abundance of sodium, magnesium and calcium, while a reverse order of abundance of both of these trios of constituents exists in regard to the salts of river-water.

By considering the transformations that take place to make insoluble compounds that constitute oceanic deposits or to generate gases to be liberated into the atmosphere, the changes that must ensue to alter the ratios of abundance of the various substances that are added to the salts of the sea by river-waters are capable of explanation, save only in regard to sodium, which, in some way not yet known, seems also to be undergoing extraction from solution.

When young Nature began to write the history of the earth upon the geological column, it was recorded that the sea was made salt in the beginning as a part of the design of the sublime system of terrestrial adaptations. There is direct evidence that the ocean in the early part of Paleozoic time was highly saline, for there were deposited from the waters of the Silurian Sea saliferous strata which constitute the Onondaga salt group and the Trenton and Chazy limestone series, in which the relics of marine organisms largely abound, to prove that they result from the sediment deposited by the ocean in that age. The salts of the sea have fed, throughout the ages, countless living things which have thronged its waters and whose remains now form the rocks of continents or lie spread in beds of unknown thickness over an expanse of the bottom of the ocean exceeding, by eighty million square miles, the total land surface of the earth; they have lent the substance to build the fringing reefs of the land and all the coral islands of the sea, and there are at present, on the basis of an average salinity of three and one half per cent., in the 324,000,000 cubic miles of water which make up the ocean, more than 11,000,000 cubic miles of salt. This is sufficient to cover the areas of all the lands in the world with a uniform layer of salt to the depth of more than a thousand feet.

What force could move such a mass on the dry land? Yet, so marvelously is its enginery balanced, the ocean has received this great burden, without growing any fuller, and has given perpetual motion to it at the summons of the sunbeam, the zephyr, the polyp.

The salinity of the ocean in all parts of the world is as nearly the same in the proportionality of its constituents as is the blood of a human being in different parts of the circulatory system. To evolve on this planet a world, such as this in which we live, the salinity of the ocean is indispensable. The office which the ocean performs in the economy of the universe by virtue of its saltness, it could not perform were its water altogether fresh.

If the sea were not salt, there would be no coral islands and reefs to give variety to its features; marine organism could not operate upon the specific gravity of its waters, nor give diversity to its climates; neither could evaporation add dynamical force to its circulation, and its waters, ceasing to contract with the lowering of their temperature below 39° Fahrenheit, would give but little strength to its currents.

It is through the agency of the salts in the waters of the ocean that the necessary powers are derived to cause it to exercise, through its circulation, a governing influence upon heat transference and climate and upon the development of vegetation and the well-being of the myriad forms of life in the world.

The three great factors in accounting for the system of currents in the ocean, by which it becomes the great heat distributor of the globe, are changes of temperature, the winds and salinity. The last mentioned becomes an important factor through the immediate and essential differences in specific gravity and consequent differences of level that it produces in different parts of the ocean through the action of evaporation and rainfall.

If, through the fall of rain upon a portion of the ocean or through the action of evaporation in the surrounding parts, the waters of that portion become lighter than the rest down to a certain distance below the surface, two different kinds of motion will immediately occur. The lighter water will be lifted by the surrounding heavier waters until there is no difference in pressure between its lower boundary and the surrounding waters at the same depth; but, as its pressure at all levels above this lower boundary will now have become greater than that of the surrounding heavier waters, it will instantly begin to displace and overflow them. This movement of the lighter water will require considerably more time than the movement of the heavier waters by which it was lifted and continues to be lifted, as its level sinks by lateral diffusion, because the sum of the differences of pressure which caused the lifting of the lighter water was, in the first place, greater than the sum of the differences that caused its lateral diffusion. Secondly, the differences of pressure that caused the first movement must extend all the way to the bottom, whereas those which cause the latter extend no deeper than the lighter stratum itself, and, even within the extent of that, have their chief effect confined to the surface strata.

On the other hand, when the equilibrium of a mass of water is disturbed by causes that do not diminish the specific gravity, the disturbance must extend down to the bottom, and the differences of pressure at all levels beneath the surface must be equal. The equilibrium is then restored by a general movement of the whole mass, which movement is sensible in inverse proportion to the mass that is set in motion. This is the essential cause for the difference in strength between the currents observed in salt and fresh waters, for, of all the current-producing causes which act in fresh waters, only the one resulting from variations of temperature can sensibly affect the specific gravity, while the specific gravity of sea water, besides being much more affected by variation of temperature, is still further influenced by the fresh water which rains upon the surface of the ocean. If the whole basin of the ocean were filled with fresh water and exposed to the most extreme meteorological influences, the currents produced would not be nearly equal either in size or strength to those observed in the waters of the ocean.

So the saltness of the sea is involved in all the great subjects into which the ocean currents and ocean circulation enter. Having contributed to the growth of the continents, it has in a like degree peopled them by influencing human mi-

grations through the streams of the ocean upon which the race of man was spread to the distant archipelagos at a time when there were only rudimentary means for struggling against the forces of nature. Besides its influences in geology and anthropology, it is concerned to a marked extent in the climates of the earth and of the sea, and in their botany and zoology.

THE EFFECT OF SCIENCE ON HISTORY

By Dr. SAMUEL FLAGG BEMIS

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LAST December there occurred in the city of Washington one of the most remarkable exhibitions of scientific studies which could be found anywhere on the face of the globe. Back in 1902, through the munificence, particularly through the farsightedness of the late Andrew Carnegie, there was created, with an income now upwards of twenty-two millions of dollars, an institution for advanced research in the realm of pure science. Under this organization have been brought together a band of scientists who ask no more than to be provided with ways and means to carry on their abstruse but epoch-making studies. And so these men are now busy in inquiring into the scientific explanation of such things as magnetic activity, the reason why radio waves hit a "ceiling" in the atmosphere and bound back to the earth; the reasons for earthquakes and volcanic action, with the possibility of charting earthquake areas in order to prophesy where the next quake will come; the means by which the plants catch solar energy and store it up in the earth for the use of man as fuel and food, with the possibility ahead of capturing solar energy and transmuting it into great fuel and food supplies for human beings. The exhibits which were brought together from the four corners of the earth by the Carnegie Institution of Washington afford a striking illustration of the ways in which scientific discoveries will modify our life in the future even more than they have in the past.

These scientific discoveries, so graphically exhibited by the Carnegie Institution, raise most interesting questions for the historian as he looks back over their history and tries to look forward to the future of science and of man.

Is it possible to measure history in terms of science? Is it possible to discover a scientific interpretation of history which will be as important an addition to the field of knowledge as has been the theory of evolution? There are some reasons to believe that some future Newton will hit upon this and that he will give an entirely new interpretation and impetus to the study and to the teaching of history. It will give us a new perspective of our place in the ebb and flow of human affairs and in our relation, not only to each other, and as nation to nation, but in the large sense of our relation to this earth and to the great universe of which this earth is a relatively insignificant and by no means a permanent fixture.

It is easiest to explain the possibility of such an interpretation by casting a historical glance backward and noting the rate at which man since the dawn of history has increased his control over the forces of nature, and then, having noticed this, to compare the rate at which he has secured control over his own nature. In such a comparison the effect of science on human history may be realized.

One of the most unusual things for the student of history to realize is that our age of *so-called* "modern" history, the

years since the discovery of America, is but a brief part of the history of mankind, whose life on this globe goes back at least 500,000 years and probably earlier. The present era of modern civilization and modern science is just the frosting on a very deep and very thick cake, none too savory at the bottom. To-day we are at the top, in material things, of the long process of civilization. We are in possession of scientific tools undreamed of by the great thinkers of antiquity and by our own grandfathers and even fathers. This is because science, with ever increasing rapidity, has been giving to man more and more control over the physical forces of nature. In the future even more than in the past, as the Carnegie Institution exhibition forecasts, we are to expect that the contributions of science will give us increased control over these forces, and over new forces which we have not yet discovered, which to-day we can not visualize even with imaginations already attuned to the startling scientific developments of our age.

For the greater part of human history man has lived without the benefit of science. Some old men listening in to-night can remember back into what seems a different world, so far as modern scientific inventions are concerned. Never did they dream in their wildest dreams of youth that, for example, they would be sitting to-night in their own homes listening to a voice from Washington. One does not have to go back many lifetimes to get beyond the touch of modern life altogether, so far as the achievements of the scientific miracles of recent generations are concerned. The farther back one goes the more static and stationary life is. Let us start at the dawn of history and observe the rate of progress of science since then.

Man's first discoveries were few and far between. It was hundreds of thousands of years before our early progenitors discovered how to make and use fire, the first great invention which profoundly changed habits of human life. Doubtless it was thousands of years after the discovery of firemaking that the bow and arrow was invented, again changing stupendously our remote forefathers' way of living. From then to the domestication of animals must have been another long period, but shorter than the distance from the discovery of how to make fire to that of how to make the bow-and-arrow. From domestication of animals to agriculture, to weaving, to other important steps in the control of natural forces were steps far apart, but, it is important to notice here and to remember, ever closer together in time, as civilization advanced. It seems pretty certain that if we knew all the facts we should find that man's control over the forces of nature has proceeded at a constantly accelerating rate—like the steam exhaust of a locomotive getting up speed, at first the puffs are slowly spaced and labored, then they come faster and faster, almost indistinguishable from each other as the engine approaches full speed. So with our civilization as it has been getting up speed. From the dawn of civilization down to the time of the ancient Greeks, that is to say, for perhaps some three thousand years, the number of epoch-making scientific achievements was very small—that is, from the invention of writing to the days of Aristotle. For the next fifteen hundred years following the discoveries of the Greek scientists, science, relatively speaking, rested on its oars. Men and women in the Roman world lived, worked, traveled, wore the same kind of clothes, ate the same kind of food, used much the same kind of tools, raised much the same kind of crops and went their separate ways in much the same way that they had in the time of Pericles. Some improvements and changes, yes, but none such as to transform very much confirmed habits of living and thinking. Then came the Renaissance and a number of epoch-making scientific inventions and discoveries—the compass, the sphericity of the earth, and with these the new world and the new geography—

the discovery of the solar system and with it a new conception of the place of man and his earth in the larger scheme. Only roughly fifteen hundred to two thousand years had now intervened between epoch-making discoveries; whereas previously such things did not occur except three or four thousand years apart, and even before that, in stretches of six or eight thousand years. From 1400, the time of the Renaissance, to 1750, the age of absolute monarchy at its apogee in Europe, the world was profoundly affected by science. It was in the eighteenth century, for example, that the beginnings of modern chemistry and physics, and with them of medicine, were laid. After a period this time of only three or four hundred years, man, thanks to the increasingly influential aid of science, had again perhaps doubled his control over the forces of nature and in a much shorter time than it had taken him to double his scientific capital in previous ages. Think of the advancements which took place in the next seventy-five years, between 1750 and 1825—the invention of power machinery, particularly of steam power, and the industrial revolution which was a consequence. If we look on our stock of scientific inventions as one looks on his capital invested in a bank or elsewhere, we see that once it took man, say, three or four thousand years to double his little stock of scientific capital; later he doubled it in half that time, namely, in about fifteen hundred or two thousand years, and that he continued to double an increasingly large scientific capital in increasingly short periods of time. From 1825 on one can appreciate readily enough the rate at which science has progressed, until now it seems that about every decade or two we double the control which science has gained for us over natural forces. And science is still speeding along. We are only beginning to get up speed. Almost over night the world of material things around us seems transformed.

What I have just said is, of course, to some extent conjectural. But if we knew enough of the facts and of the history of man for, let us say, the last twenty-one or two thousand years, we might be able to plot a curve representing the rise of science from, let us say, 20,000 B.C. to 1925 A.D. For the first ten thousand years that line would run along the bottom of the page with only a small ascent marking the advance of science from the invention of fire-making to that of the bow-and-arrow. After that during the next five thousand years, from bow-and-arrow, say, to domestication of animals, to agriculture, to the invention of writing, the curve would rise as much as it had in the previous ten thousand. From the invention of writing to the time of Greek science the curve would again go up, in now less than twenty-five hundred years, to a degree equalling the whole sum of previous advance. As our civilization has been getting up speed our stock of scientific knowledge has doubled itself at increasingly short intervals. Possibly it has acted somewhat like a dollar out at interest, which might at first at infinitesimal rate of interest double itself in ten thousand years, then the two dollars to double in five thousand years, the resulting four dollars in twenty-five hundred years, the next eight dollars in twelve hundred and fifty years, and so along, until at length rapidly larger sums are doubling themselves at very short intervals. Very roughly speaking, this suggests the way our stock of scientific knowledge has been increasing. If we knew all the facts, I repeat, we might possibly figure out a mathematical measurement of the advance of science, and thus discover a dynamic law of history—once suggested by Henry Adams—which would be as important in thought as the theory of evolution.

It is quite possible that between 1925 and 1940 science will have advanced as much as it has done in hundreds of years in the past. We know we are now going ahead at a stupendous speed. Can we keep this up indefinitely? Are we likely

to get going so fast that we are in danger of running off the track? This is what many thinkers to-day want to know, and they are calling on the historian to tell them.

Remembering this ever-increasing, this dizzy speed of scientific progress in recent times, let us note whether human nature, human physiology, human psychology has been changing. If at all, these factors have changed only very slowly. We are somewhat different now than in the time of Tutankhamen. Thanks to medical science, we live twice as long. Our social organization and our political organization are somewhat better, but our progress in these directions has been painfully slow. While we have been speeding ahead so fast in getting control of physical and chemical nature we have done woefully little in getting control of human nature. Our human nature, that is, our human body, is not very much different now than it was in the time of ancient Egypt. We fight wars, we experience revolutions and we do them in more deadly and more rapid ways. We have the same human hatreds, fears, hopes and loves. What if human nature should get out of control in another great war, in let us say 1940? What if in 1940 mankind should loose, for purposes of destruction, the physical forces which science will have harnessed in the next fifteen years? The answer is suggested to me by some words of Secretary of Commerce Herbert Hoover, which he is quoted as having used in an Armistice Day address at Los Angeles: "The world has learned many lessons from the war, but none more emphatic than that its increasing terribleness will, if repeated again, destroy civilization itself. The mobilization of a whole people into war, the inventions of science turned to destruction and the killing of men will make any other great war the *cemetery of civilization.*"

This is what interests the historian as he turns his attention to the work of modern science as an ever-increasing and powerful factor in human life —the most powerful material factor there is to-day. The historian, noting the increasingly potent factor which science is playing of late years in human affairs, is impelled to ask the questions: Is the control of natural forces we are now achieving in such increasing measure, is this control compatible with our control over human nature? Will our startling and ever more startling scientific inventions get out of hand, through defects of human nature, and end us in a catastrophe that will make us begin all over again? The historian of to-day is becoming more concerned with the relation of science to society in recent times. He will be even more concerned in the near future. If the teaching of history can be presented in such a way as to make the student know where civilization is now and whither it is going, it can in this way emphasize the vital necessity of adjusting human nature to scientific progress, then history may come to have a practical value to be measured in the saving of human lives by the millions and in the saving of civilization itself. The lessons of history will be more availed of, as they were in the Washington Conference for the Limitation of Armaments in 1921, which enabled millions of people to avoid a terrible war. Thus does the study of history become as practical and valuable an everyday sort of thing as chemistry. Indeed it is more so, if one realizes that some great cataclysm in the future if not prevented may knock the props out from under science itself.

The study of history, in terms of human relation to science, is the only way we have to throw a beam ahead on an uncertain road. It is as indispensable to civilization, in these days of rapid scientific inventions, as is a headlight to a powerful motor car speeding ahead on an indifferent country road. It is a conception of history as the headlight of civilization which makes the teaching of it one of the noblest tasks of life.

ASTRONOMY AND AUTHORITY

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About the time of the death of Copernicus in 1543 and the publication of his now famous astronomical treatise, there were definite signs of a breaking away from the authority of Aristotle in several fields of scientific inquiry, although the most immediate effect was upon astronomy. The movement was slow in gathering strength, for the ecclesiastical power of the period dealt summarily with those who questioned its dogmas, especially if it thought its position to be imperiled. It crushed many brave spirits under its iron heel.

Yet by the end of the sixteenth century the number of "dissenters" had increased considerably. The clerics now became thoroughly alarmed at the growing "heresies" and, hoping to put an end to them, singled out an outspoken believer in the Copernican system, the eminent Giordano Bruno, and ordered him to recant on pain of being put to death at the stake. Bruno refused to recant and thus went to his death; but his dying words live forever in the hearts of men: "I yielded to none . . . in constancy, and I preferred a spirited death to a cowardly life."

Bruno was a contemporary of a number of other fearless thinkers who could not be crushed, among these the fiery Galileo (1564–1642) and the painstaking Kepler (1571–1630), who between them were destined to complete the destruction of the Ptolemaic-Aristotelian cosmogony, which assumed the earth to be fixed, with the sun and the rest of the heavenly bodies circling around it. The burning of Bruno at the stake served mainly, after the first hush of dread had passed, to lash the Ptolemaic-Copernican controversy into a fury, out of which the Copernican system emerged triumphant.

Two outstanding achievements in the field of astronomy served to make this seventeenth century triumph completely possible. One was the perfection of the telescope and its use by Galileo, and the other was the discovery by Kepler of the laws of planetary motion, the keynote of which was the substitution of elliptical for circular orbits to explain the movement of the planets about the sun.

Galileo and Kepler were both eminent mathematicians and astronomers; they held professorships in prominent universities; and they accepted the Copernican theory early in their careers. They were acquainted with each other, at least by correspondence; apparently secured considerable consolation in writing back and forth about their work and their troubles with ecclesiastical despotism; and appreciated the dangers they were running in holding unpopular views. Galileo remarked in 1597 in a letter to his friend that he was withholding some of his arguments, for he did not desire to become, as he put it, "an object of ridicule and scorn . . . so great is the number of fools." Galileo had a bitter tongue and did not mince words on occasion.

At the University of Pisa in his native city, where he received his education and where he later held a professorship, Galileo soon brought unpopularity upon himself because of his original thinking and his keen desire to get at the truth, which desire amounted to a passion with him. His father, an impoverished Italian nobleman, had tried unsuccessfully to make a merchant out of his son and, failing, had sent him to the university to study medicine. But Galileo was interested in pure science, and this interest could not be suppressed. Sitting in the

cathedral at Pisa, during a service, his attention was caught by a swinging chandelier above him. In a spirit of curiosity he timed the oscillations by his pulse beat—for watches had not yet been invented—and noted the curious fact that, although the oscillations were dying down, the time of each swing of the chandelier remained unchanged, a discovery which formed the basis for the subsequent construction of the pendulum clock. Experimenting with pendulums of varying length on his return from the cathedral he discovered a second important fact, *viz.*, that a longer or shorter time of swing is secured by changing the length of the pendulum; and combining the two discoveries, he invented the first instrument for recording the pulse beat of a patient. During this same period of medical study, he accidently overheard lessons in Euclid being given at the home of a friend and induced the tutor to give him lessons also. Soon, the study of medicine forgotten, he was deep in mathematics and physics, mastering the writings of Archimedes and making suggestions along scientific lines which brought him to the attention of the premier mathematician of Italy, who secured for him the chair of mathematics at Pisa.

Here at the very beginning of his career, Galileo performed his famous experiment of dropping a light and a heavy ball of metal from the top of the leaning tower of Pisa to disprove Aristotle's dictum that a heavy body falls faster than a light one. Aristotle's assumption is the common sense assumption, for it is in every one's experience that a piece of paper flutters to the ground more slowly than a stone drops. Yet the difference is due only to the resistance of the air, neglecting which, the paper and the stone would fall with the same speed, as experiments in vacuo amply demonstrate.

In his experiment Galileo used a hundred pound cannon ball and a half pound weight, the compactness of the objects rendering the resistance of the air negligible. He released them together. But as the cannon ball and the weight struck the ground simultaneously before the astonished eyes of the antagonistic crowd that had gathered, only angry mutterings arose. Galileo was called a sorcerer and magician, for not only did the result violate common-sense impressions, but the great Aristotle had taught the very opposite. And what Aristotle taught was not to be questioned, and so, his colleagues reasoned, Galileo must have resorted to witchcraft! The leaning-tower-of-Pisa experiment was but an illustration of how in one way or another Galileo thundered forth his anathemas against the blind antiquity-worship of the day, until his enemies in Pisa forced him to resign his professorship. Luckily, however, his fame had spread and in 1592, still under thirty years of age, he was invited to come to the University of Padua, where he continued his experiments but curbed his utterances somewhat until after his reelection in 1598.

Then came the martyrdom of Bruno, and the spirit of Galileo boiled within him. He watched his opportunity and found it in the appearance of a new and brilliant star in 1604. Here was an object-lesson. How account for a strange star in the never-changing, immutable heavens of the Aristotelians? He unleashed his bitter tongue again. Before large audiences he flayed his enemies and for the first time came out boldly for the Copernican system. Soon he was the storm center of the controversy, with the clerics watching his every move. But Padua was quite tolerant religiously and as long as Galileo stayed there he was safe from actual persecution.

It was at this period that he received word from Holland regarding a crude magnifying contrivance, which his inventive genius seized upon and perfected into the telescope. His first improvement enabled him to see objects nine

times as large and three times as near. He quickly followed this with another instrument which magnified objects nearly a thousand fold and brought them thirty times nearer. This he pointed to the heavens with further devastating results for the Aristotelian cosmogony. Again his trenchant pen and bitter tongue flayed the opposition. "Where is your perfect moon," he shouted, "when through my telescope it shows itself to be all scarred and indented?" "Why assume the earth to be the center of the universe," he continued, "when I see four bodies circling around the planet Jupiter?" His opponents were beside themselves. One prominent critic insisted that since the moons of Jupiter could not be seen with the naked eye, they did not exist. Another simply refused to look through the "devil's glass."

"Oh, my dear Kepler," writes Galileo, "how I wish we could have one hearty laugh together. Here at Padua is the principal professor of philosophy, whom I have repeatedly and urgently requested to look at the moon and planets through my glass, which he pertinaciously refuses to do. Why are you not here? What shouts of laughter we should have at this glorious folly. And to hear the professor of philosophy at Pisa labouring before the grand duke with logical arguments, as if with magical incantations to charm the new planets out of the sky."

With his telescope, Galileo continued to "push back the heavens" and to add to his fame. He discovered a sun spot and by watching its changing positions calculated that the sun revolves on its axis every twenty-four days. He resolved the Milky Way into myriads of tiny stars. He discovered the rings of Saturn. And in scores of other ways he opened up the heavens as they had never appeared before.

By this time Galileo had become the idol of the Venetian republic, under the protection of whose tolerant religious attitude he should probably have remained. But he had long desired to be back in his home in Tuscany, in spite of its bigotry and intolerance and the nearness of Rome, so in 1610 he returned, accepting a position in Florence, where he continued his researches in physics and astronomy and his criticism of the Aristotelians. The ecclesiastics now saw their opportunity and began stirring up Rome, until finally Galileo was sent for in 1616, his works were put under the ban, and he was enjoined on pain of torture and imprisonment to cease his "heretical opinion." Under duress, he promised never to teach the Copernican doctrine again, and this forced promise he abided by impatiently for fourteen long years.

In the meantime, Galileo's friend Kepler was busily engaged in Germany destroying the Ptolemaic system, if not in as spectacular a manner, yet in a way which struck at its very roots.

Kepler had had troubles of his own. Born in an atmosphere of poverty and domestic bickering, sickly as a child and his eyesight almost ruined through a serious illness, Kepler started life with many handicaps. But he possessed a dogged perseverance and a genius for mathematics which soon won him a number of friends. These aided him in getting to the University of Tübingen, which he entered at the age of seventeen. Here he distinguished himself under the professor of mathematics, Michael Maestlin, who was an ardent supporter of Copernicus and who deeply influenced young Kepler. At twenty-three, Kepler was already installed as professor of mathematics at the University of Grätz.

He now began to speculate about the general plan of the solar system. He knew that there were some glaring discrepancies between the circular orbit theory of planetary motion and the observed facts, and he knew that the six planets then known (Mercury, Venus, Earth, Mars, Jupiter and Saturn) moved

in their orbits at variable speeds and that the farther a planet was away from the sun the more slowly it moved. The way Kepler went about his problem is highly illuminating. Questioning the theory of circular orbits, he tried every conceivable orbit he knew anything about, triangular, pentagonal, hexagonal, and so on, in each instance testing his hypothesis with the observed facts and discarding the hypothesis when he saw it did not fit.

At first, however, he did not have very accurate data to go by, and he published his earlier theories in 1596, thinking the results accorded fairly well with the facts. The effect of the publication was to put him in close touch with Galileo, in then far-off Italy, and to receive an invitation from the greatest astronomical observer of the age, Tycho Brahe, to come to Prague, in Bohemia, and test his hypotheses with the observations there recorded. Kepler accepted the invitation, went to Prague and tested his theories, found they did not accord with Brahe's observations, and unhesitatingly discarded them.

But he had won the friendship and admiration of Brahe, with the result that he accepted an offer to work with him under the patronage of King Rudolph of Bohemia. Here was an unusual combination, a great mathematician working hand in hand with a great observer. To be sure Brahe died soon after Kepler's arrival from Grätz, but the former's wonderfully accurate observations of planetary motion were at Kepler's disposal. Furthermore, as the result of a promise made to Brahe before the latter's death, Kepler himself completed a series of observations he and Brahe had started and published them after considerable difficulties a number of years later under the title of the Rudolphine Tables, in honor of King Rudolph, who had also died in the interim. These tables were of the utmost importance and for hundreds of years served navigators much as the Nautical Almanac of England serves navigators to-day.

Long before the publication of these tables, Kepler had begun to correspond with Galileo, both with respect to the Copernican theory and the construction of telescopes. While Galileo was confounding the ecclesiastics of Italy by breaking through the heavens with his telescope, Kepler was struggling along in a new position at the University of Lenz, in Austria, to which place he had gone after the death of King Rudolph, worries besetting him on every hand. Being short of funds, he had begun publishing an almanac through which he practiced as an astrologer, a practice indulged in by Galileo, and also by other noted men of that period, not to mention the motley crowd who knew nothing whatever of the movements of the heavenly bodies but practiced as charlatans pure and simple.

Kepler's family had been very ill and had almost starved, his salary was in arrears, his mother had been accused of sorcery and had escaped torture only because of his personal intercession, and his efforts to raise money to have the Rudolphine Tables published were meeting with little success. He was hardly in the mood to indulge in laughter at the time his friend Galileo wrote him wishing the two could be together.

But through all his troubles, Kepler kept doggedly on with his speculations as to planetary motion. His earlier theories discarded, he tried others, only to discard these in turn as not according with the facts, until at last he hit upon elliptical orbits with the sun at one of the foci, and, lo and behold, the hypothesis worked! We can well imagine his joy (for the quotation to be given presently indicates that he gave vent to his feelings occasionally), when he applied Brahe's observations and found that they accorded precisely with his theory.

Kepler's great revelation that the planets move in elliptical orbits about

the sun paved the way for his second discovery. He had been puzzled, also, by the variations in the rate at which planets move. Observations showed that a planet does not move with any uniform speed, but moves more slowly at certain times than at others. When near the sun it moves fastest; when farthest away it moves slowest. Applying the same trial-and-error method to this problem, he finally discovered the curious fact that the observed variations in speed are such that planets sweep out equal areas in equal times—which is to say that, if an imaginary line is drawn from the sun to a planet moving in its elliptical path and one end of the line is considered as fixed at the sun while the other end moves with the planet, the quasi-triangular areas swept out by the line in like periods of time are always the same.

Kepler published his first two laws in 1609 in his book on the "Motion of Mars," at the time Galileo was at the height of his fame in Florence. But Kepler was not yet satisfied. There was still another problem which was puzzling him, and this related itself to the periods of the planets, *i.e.*, the lengths of time they take to complete their orbital paths. These periods, it had long since been observed, were not the same for the different planets. The greater the average or mean distance of a planet from the sun the longer does it take to complete its orbit. Was there any exact relationship, Kepler now asked himself, between the average or mean distances of the planets from the sun and their respective periods?

Again, he experimented mathematically. Once more he tried various combinations. He squared the periodic times and the mean distances; he cubed them; he raised them to higher powers—all the while making comparisons to establish a possible relationship. And finally, for a third time, he hit upon a great truth. He discovered that there is an unvarying ratio existing between the mean distances and the periods, *viz.*, the squares of the periodic times (t) of the planets are as the cubes of their mean distances, (r) – $t_1^2 : t_2^2 :: r_1^3 : r_2^3$. In other words $\frac{r^3}{t^2}$ is a constant, or $r^3 = kt^2$. For example, consider the earth's mean distance from the sun as one unit and its period as one year. On the same basis Mars' calculated mean distance from the sun is about 1.5 units. According to Kepler's third law, the earth's period squared is to Mars' period squared as the earth's mean distance cubed is to Mars' mean distance cubed; or $1^2 : x^2 :: 1^3 : (1.5)^3$

$$\frac{1^2}{x^2} = \frac{1^3}{(1.5)^3}\ \textit{i.e.},\ x^2 = (1.5)^3$$

or $x = 1.9$ years, which is the correct period for Mars as borne out by actual observation.

Kepler published his third law in 1619, at which time he wrote regarding it in the following words:

> That for which I joined with Tycho Brahe, for which I settled in Prague, and for which I have devoted the best part of my life to astronomical contemplations, this at length I have brought to light. It is not eighteen months since the first glimpse of light reached me, three months since the dawn, very few days since the unveiled sun, most admirable to gaze upon, burst out upon me. Nothing holds me; I will indulge in my sacred fury; I will triumph over mankind by the honest confession that I have stolen the golden vases of the Egyptians to build up a tabernacle for my God, far away from the confines of Egypt. If you forgive me, I rejoice; if you are angry, I can bear it; the die is cast; the book is written; to be read either now or by posterity, I care not which; it may well wait a century for a reader, as God has waited 6,000 years for an observer.

In writing as he did, Kepler realized full well that the ban of the church would be upon his revelations, for, three years before, the College of Cardinals had suppressed his other writings with those of Copernicus and Galileo. But the arm of the church could not reach Kepler in Austria as easily as it could

Galileo in Italy, and so his person was safe. How he regarded his critics is well summed up in what he wrote on a previous occasion:

> If any one be too dull to comprehend the science of astronomy, or too foolish to believe in Copernicus without prejudice to his piety, my advice to him is, that he should quit the astronomical school, and condemning, if he will, any or all the theories of philosophers, look to his own affairs, and leaving this worldly travail, go home and plough his fields.

Kepler's contributions to astronomy were indeed great. The discovery of any one of his three laws would have been sufficient to give him lasting fame; but he did not stop there. In the course of bringing the Rudolphine Tables to completion (they were not published till 1627), he incorporated his new discoveries and set down the observed facts regarding the planets in such a manner that their locations could be easily computed far in advance. In addition, he came nearer to estimating the true distance of the earth from the sun than any astronomer since Hipparchus had done; he made a profound study of comets, and his explanation of why their tails point away from the sun is almost identical with that accepted to-day; and the prodigious amount of tedious computing he did, without logarithms or modern tabulating devices, is almost beyond comprehension. Napier, the inventor of logarithms, was a contemporary of Kepler, but his invention came too late to benefit the latter very much. When Kepler heard of the invention, however, he was enthusiastic over its possibilities, adding that logarithms would triple the life of the astronomer.

It is difficult for us to conceive how startling the discoveries of Kepler must have been in his own day. That planets move in circular orbits was a deeply rooted belief, handed down from the ancient Greeks and accepted unquestioningly even by Copernicus. Elliptical orbits was a most revolutionary idea even to Galileo, who was quick to accept it, however, and make use of it in his lectures against the Ptolemaic system, as soon as Kepler had set forth his proofs.

Kepler died in 1630, soon after the publication of the Rudolphine Tables. The same year, after fourteen years of enforced silence, Galileo published his great work on the Ptolemaic and Copernican systems, written in dialogue to conform with the spirit of his promise to the ecclesiastical authorities. The book immediately created a tremendous stir, and, although it was later suppressed and Galileo was forced to recant to save his aging body from torture and for a few more years of research, the mischief had been done. The new knowledge spread throughout Europe. The demolition of the Aristotelian cosmogony was complete. Between them, Kepler and Galileo had placed astronomy on a secure scientific basis, from which it could proceed to perfect its principles.

But it was not only the Aristotelian view of the universe that was crumbling during this period. The authority of Aristotle in biology and physics was likewise being swept aside. Kepler and Galileo did not stand alone. Contemporary with them, Gilbert in physics and Harvey in biology were shattering the Aristotelian tradition.

Galileo, as has been noted, was disconcerting the Aristotelians not merely in the field of astronomy but in that of physics as well. Both he and Kepler advanced the study of optics. The latter worked out the principles underlying the refraction of light through various media, such as air and glass, to the point from which the laws of refraction were later derived (by Snell), while Galileo worked out many of the important principles underlying lenses in addition to perfecting the telescope. He also invented what was probably the first thermometer, and began the quantitative study of heat.

In dynamics, a most important department of physics, Galileo's contributions equalled in importance his work in astronomy. Following his famous experiment with falling bodies at the leaning tower of Pisa, which so antagonized his colleagues and others that he was forced to give up his professorship at the university there, Galileo worked out the laws of falling bodies now familiar to every schoolboy. He had noticed that a falling body does not descend at a uniform speed, but that its velocity increases as it falls and that the longer the time during which it falls the greater does its velocity become. So he set about trying to find a definite mathematical relationship in falling bodies between time of fall, speed and distance, just as Kepler had faced the problem of the relationship between planetary orbits, distances and periods. Galileo made a number of interesting experiments with balls rolling down inclined planes, taking care to minimize the effects of friction and constructing an ingenious yet simple timing device. After collecting sufficient data he applied his mathematics and found that the observed increase in velocity when a body falls is directly proportional to the time of falling, *i.e.*, the ratio of the velocity (V) to the time ("t") is a constant—$\frac{V}{t} = K$ or $V = Kt$. From this he derived, as a simple corollary, that the distance of descent ("d") is always proportional to the square of the time of falling. Take a body falling from rest, for example: Distance traveled equals the average velocity multiplied by the time, and if the velocity is constantly increasing, the average, starting from rest, is $\frac{\text{“}O+V\text{”}}{2}$. Hence $d = \frac{(O+v)}{2} \cdot t$, or $d = \frac{vt}{2} = \frac{Kt \cdot t}{2} = \frac{1}{2}Kt^2$, *i.e.*, the distance of fall varies as the square of the time.

As in the case of Kepler's laws, Galileo did not explain *why* these ratios must be so. He merely stated the facts. It took Newton in the next generation to explain both Kepler's and Galileo's discoveries. With respect to the foregoing equation, it was later shown that "K" is the value of the force of gravity at the earth's surface. The significant point here is that Galileo's work in dynamics swept aside the misconceptions of Aristotle regarding falling bodies and laid a secure foundation upon which future scientists could build. Galileo also worked out mathematically that the path of a projectile, which gunners had long since recognized as deviating from a straight line, is a parabolic curve and that there is a direct inverse relationship between weight and distance when bodies are acted upon by a given force, *e.g.*, a force that will move a two-pound weight through one foot of distance will move a one-pound weight exactly two feet or a half-pound weight exactly four feet.

In concluding this brief sketch of the most important of Galileo's contributions to physics, it is fitting to recall that, when at the age of sixty-nine he saved his body from the torture rack and the flames to which an ecclesiastical despotism stood ready to consign him unless he recanted with respect to his astronomical teachings, he was undoubtedly preserving himself for the uncompleted work on dynamics and statics he had started over forty years before at Pisa. It was during these last years that he finished his experiments. Under the watchful eyes of the clerics, a virtual prisoner, and with failing health, the great Galileo had passed seventy when he prepared to hurl his last thunderbolt into the ranks of bigotry and authority. Under tremendous handicaps, he published in 1636 the now famous "Dialogues of Motion." The devastating effect of this great work on preconceived ideas was not appreciated at once by the clerics, but it apparently had struck home by the time of Galileo's death six

years later, for he was denied decent burial, all his manuscripts were seized and most of them were burned, and even his will was vigilantly scrutinized and disputed.

Happily, Galileo's older contemporary in physical advance, William Gilbert (1544–1603), was born in England and not under the eyes of Rome. For England in Gilbert's day had become quite tolerant as compared with the England of Roger Bacon's day. Gilbert thus escaped persecution, although his researches in electricity and magnetism met with the same type of bigoted opposition as did Galileo's in mechanics. How the first great man of science in England since Roger Bacon regarded his opponents is well expressed in the preface to his monumental work, "De Magnete," published during the year of Bruno's martyrdom in 1600:

> Why should I submit this noble science and this new philosophy to the judgment of men who have taken oath to follow the opinions of others, to the most senseless corrupters of the arts, to lettered clowns, grammatists, sophists, spouters, and the wrong headed rabble, to be denounced, torn to tatters, and heaped with contumely! To you alone, true philosophers, ingenuous minds, who not only in books but in things themselves look for knowledge, have I dedicated these foundations of magnetic science.

How his bold stand for observation and experiment must have rankled in the minds of the guardians and protectors of the written word!

Gilbert was educated at St. John's College, Cambridge, evidently specializing first in mathematics and later in medicine. He received the degree of M.D. in 1569 at the age of twenty-five. Following the custom of educated men of the day, he now spent a few years in travel on the continent, visiting Italy, then the intellectual center of the world despite its religious intolerance. He settled down in London to practice medicine in 1573, and soon established a wide reputation both as a physician and as an experimentalist along chemical, electrical and magnetic lines, his home becoming the rendezvous for a group of admirers and followers who watched his experiments and accepted his conclusions. His fame reached its height during the year the "De Magnete" was published, in 1600, when he became president of the Royal College of Physicians and chief physician to the court of Queen Elizabeth. He died three years later.

Gilbert discovered some of the outstanding facts which form the basis of modern electricity and magnetism, and he was the first to distinguish between electrical and magnetic phenomena. He discovered that the earth is a giant magnet and he invented the term "pole" to explain certain of the observed facts. He was also the first to distinguish between substances that can be electrified by friction and those that can not. These contributions will be taken up again later when we get to the more constructive developments that grew out of Gilbert's pioneer work.

Great as were Gilbert's contributions, his greatest service undoubtedly lay in clearing away some of the weeds of misconception which had grown up about the subjects of electricity and magnetism since ancient days and which constituted a part of the Aristotelian dogmas of his period. This service was all the more valuable since alchemy, astrology and magic were all involved in the misconceptions Gilbert attacked, and, until they were cleared away, little progress along the lines of chemistry as well as in the field of electricity and magnetism could be expected.

The phenomena of magnetism had long been mixed up with magical practices. As Gilbert says, "the lodestone was accused of producing melancholy, of making love philters, of losing its power when rubbed with garlic, and regaining it when smeared with goat's blood, of de-

clining to attract iron in the presence of diamond." Applying the test of rigid experiment to each of these statements in turn, Gilbert demonstrated them to be so much hocum. It had been taught that a piece of iron rubbed with a diamond becomes magnetized. Gilbert proceeded to find out if this is true. As he says farther:

> We made the experiment ourselves with seventy-five diamonds in presence of many witnesses, employing a number of iron bars and pieces of wire, manipulating them with the greatest care while they floated in water, supported by corks; but never was it granted me to see the effect mentioned.

It had been held for 2,000 years that amber alone can be excited by friction to attract other bodies. Gilbert dispelled this notion and demonstrated that many substances can be thus excited, among them glass, sulphur and resin. It had been known for thousands of years that a compass needle always points in a certain direction and many had been the speculations advanced to explain this phenomenon. Gilbert's discovery that the earth is a magnet with "poles" at the north and south furnished a simple explanation of both compass direction and dip. In this connection, he remarks in his book:

> The common herd of philosophers, in search of the causes of magnetic movements, called in causes remote and far away. Martinus Cortesius . . . dreamt of an attractive magnetic point beyond the heavens, acting on iron. Petrus Peregrinus holds that "direction" has its rise at the celestial poles. Cardan was of the opinion that the rotation of iron is caused by the star in the tail of the Ursa Major. The Frenchman Bossard thinks that the magnetic needle turns to the pole of the zodiac. . . . So has ever been the wont of mankind: homely things are vile; things from abroad and things afar are dear to them and the object of longing.

Gilbert cleared away much of the underbrush and in doing so emphasized anew the value of observation and repeated experiment as the basis of scientific investigation. As expressed in his own words and quoting again from his treatise:

> In the discovery of secrets and in the investigation of the hidden causes of things, clear proofs are afforded by trustworthy experiments rather than by probable guesses and opinions. . . .
>
> Whoever wishes to try the same experiments, let him handle the substance, not carelessly, but prudently and deftly, and in the proper way, and when the thing does not succeed let him not in ignorance denounce my discoveries, for nothing has been set down in these pages which has not been many times performed and repeated.

It would be going too far afield to indicate the innumerable ways in which Gilbert's "De Magnete" shattered existing notions regarding electrical and magnetic phenomena and laid the foundation for a better understanding of scientific truth. It is a good book to dip into. It contains many quaint and humorous as well as illuminating passages. When Galileo had seen it, he expressed his opinion about Gilbert enthusiastically:

> I think him worthy of the greatest praise for the many new and true observations which he has made, to the disgrace of so many vain and fabling authors, who write not from their own knowledge only, but repeat everything they hear from the foolish and vulgar, without attempting to satisfy themselves of the same by experience.

Gilbert did not possess the depth and scope of Galileo, nor did his work affect progress as immediately, but he nevertheless contributed in important ways to scientific advance.

While Gilbert was at the height of his fame in London, a young contemporary, destined to strike at the citadel of authority from another quarter—also an Englishman and also interested in medicine as a career—had journeyed to Padua to complete his medical training under the renowned surgeon and anatomist Fabricius. This was William Harvey (1578–1657), the celebrated discoverer of the circulation of the blood.

Like Gilbert, he became prominent as a physician in London and served royalty, first as physician to James I and later to Charles I. Harvey's contributions to scientific advance were in the field of biology.

Again, the great influence here was in breaking down the bars of unquestioning authority, and in this respect Harvey was considerably aided by the work of two outstanding predecessors, Valerius Cordus (1515–1544) and Andreas Vesalius (1514–1564), one a German and the other a Belgian.

Cordus was a botanist and the son of a botanist. In his day the relation of botany to medical practice was intimate, since the latter utilized herbs and plant products very extensively. Hence every physician was a botanist and every botanist a physician. It will be remembered that Dioscorides in the first century had written a medical botany, which because of its practical aspects had come to overshadow the earlier and better work of Theophrastus. By the fifteenth century Dioscorides was giving place to Theophrastus and with the coming of the youthful genius Cordus (who did all his work before he was 29), the still further step was taken of describing plants anew from nature instead of placing any dependence at all on the incomplete descriptions of the ancients. Cordus lectured at Wittenberg, in Germany, where he taught men to break away from the past and think for themselves. He wrote a notable work on plants, was an excellent first-hand observer and explored the botanical riches of Germany to good practical effect. In 1542 he visited Italy on a botanical expedition and died prematurely in Rome before his work was completed. He left his imprint on botanical advance in both Germany and Italy.

Vesalius, the other important predecessor of Harvey, was born at Brussels and received his medical education at the most renowned universities of France and Italy. He had a distinguished public career as a physician, serving as army surgeon in Flanders, then as professor of surgery at Padua and other universities, later as court physician to Charles V, and still later as court physician to Philip II at Madrid. He made a pilgrimage to Jerusalem in 1563 and died on the voyage home.

The great work of Vesalius lay in the biological field of anatomy. His writings on the structure of the human body have been likened by a noted historian to the discovery of a new world. Vesalius broke away from Galen, who had held undisputed sway in anatomy and physiology for fourteen centuries, and attempted to place anatomy on the firm basis of exact observation. In differing from Galen and in indicating his disgust with the crude dissections of his day, he secured the enmity of many of his fellow-physicians, but at the same time he gathered a number of followers to himself who faithfully carried on his work.

It was the influence of Vesalius which Harvey felt on arriving at Padua a half century later. Vesalius had broken with the Galenic tradition in anatomy. Harvey set himself the task of doing the same for physiology. He was not satisfied with Galen's ideas about bodily functions. In fact, no rational understanding of the dynamics of the human system was possible as long as one accepted the conclusions of the Galenic school that the arteries are filled with air. This false notion arose because the arteries are found to be empty after death.

During the early part of his medical practice in London, Harvey was appointed in 1615 as lecturer on anatomy at the College of Physicians. Here he started his carefully planned and ingeniously executed experiments which led to the discovery that the blood actually flows in a circle from the heart through the arteries and veins back to the heart again. He began teaching this

doctrine in 1619 and immediately aroused a storm of opposition from the medical fraternity. The storm raged for twenty-five years before the truth of his discovery was recognized, and in the meantime (in 1628) he published a tract on the subject which fortified his contentions with the most solid and convincing proofs. His own statement regarding his discovery, made in his tract, is of considerable interest:

> I frequently and seriously bethought me, and long revolved in my mind, what might be the quantity of blood which was transmitted, in how short a time its passage might be effected, and the like; and not finding it possible that this could be supplied by the juices of the ingested aliment without the veins on the one hand becoming drained, and the arteries on the other hand getting ruptured through the excessive charge of blood, unless the blood should somehow find its way from the arteries into the veins, and so return to the right side of the heart; I began to think whether there might not be a motion, as it were, in a circle. Now this I afterwards found to be true; and I finally saw that the blood, forced by the action of the left ventricle into the arteries, was distributed to the body at large, and its several parts, in the same manner as it is sent through the lungs, impelled by the right ventricle into the pulmonary artery, and that it then passed through the veins and along the vena cava, and so round to the left ventricle in the manner already indicated. Which motion we may be allowed to call circular.

But it must not be thought that all Harvey's conclusions were equally sound. He accepted Aristotle's assumption that many forms of life arise through spontaneous generation, and in 1651 published a treatise in which he laid the foundations for the so-called epigenesis theory of development, both of which assumptions were later proved to be false. Besides his famous discovery, his main contributions lay in breaking away from the ancients in other important respects and in emphasizing the need for first-hand observation and experiment.

With Cordus, Vesalius and Harvey, three important branches of biological study (botany, anatomy and physiology) became freed from the thraldom of authority and the ground was made ready for a further advance. But many misconceptions were still rife and others were to follow. In this field and in others, new fallacies came to be accepted as fast as the old ones were swept away, for the reason that the foundation stones had not yet been securely laid. Other great scientists were still to come and place physics on as secure a basis as Kepler and Galileo had placed astronomy, and the ancient Greeks had placed mathematics, and until then chemistry and geology and biology and finally psychology were still speculative at bottom.

The significant thing about the whole period here under consideration is that, in addition to the solid establishment of astronomy as a science, the blind acceptance of Aristotle's results (whether true or false) had come to an end and that his methods of observation and experiment, a return to which Roger Bacon three and a half centuries before had pleaded for in vain, were finally being revived. The critical angle from which Aristotle has been viewed in this article should not result in obscuring his great contributions, despite the grievous mistakes he made. It was the impossibility of separating the true from the false in Aristotle's writings, since the blind adherence to the written word forced the acceptance of the false with the true, which fettered progress. But the fetters had now been removed by a return to direct observation and experiment.

BIG GAME OF THE UNITED STATES AND ITS CONSERVATION

By E. A. GOLDMAN

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At the time of the discovery of North America, large game in abundance ranged nearly throughout the length and breadth of the continent. Deer of several kinds, browsing largely on the leaves of tender shrubs and craving shelter, lived in the forests everywhere, except in the far north. Great herds of grass-feeding animals, buffalo, antelope, elk and mountain sheep occupied the open plains or high mountains of the West. Moose, even more than the deer, were restricted to the forests, and bears were numerous wherever conditions were suitable.

With the appearance of the settlers, the clearing of the forests for farms and the occupation of the grass lands for agricultural purposes or the grazing of domestic stock, the disappearance of much of the game was inevitable. The final passing of the buffalo could not have been prevented, for great herds of buffalo have no place, as game, under modern conditions. Inevitable also was the passing of most of the antelope, originally more numerous perhaps than the buffalo.

Pressure of human occupation, therefore, together with unrestricted killing by hunters, inroads by predatory animals and other incidental factors, led to the disappearance of the game, or to its reduction to comparatively small numbers over most of its former range. Deer and moose, however, are now increasing, where accorded protection, especially on some of our national forests and national parks, which may be regarded as great natural reservoirs for game. Mountain sheep still occur in places in the higher mountains of the west and in the desert ranges of the southwest, usually in small bands, which as a rule show little or no increase, although no killing is permitted under the laws of most states. The antelope, regarded by many as the most beautiful and characteristically American of our game animals, have decreased very rapidly, especially in the past ten years. They still occur in sixteen states, many of the smaller groups unfortunately in sections where their extinction is practically certain because of local conditions. Antelope are not likely to survive except on areas where they are accorded special protection. In the west the elk, accustomed to summer largely in the mountains, and to migrate to wintering areas on the lower mountain slopes and the surrounding plains, have been forced back to winter in the higher and more inaccessible mountains. While thousands still remain in the Rocky Mountain section, chiefly in and around Yellowstone Park, and in the mountains nearer the Pacific Coast in Washington, these are mere remnants of the former great herds.

Although the general outlook may seem rather discouraging, progress is being made and much may yet be done, not only to save the remnants, but to greatly increase numbers and restore game to sections from which it has dis-

appeared. In order to deal intelligently with the problem we must first understand and consider the requirements of the game and all the factors that may result in decreases or increases in number.

The importance of establishing game preserves, national, state, municipal and private, is becoming more generally recognized; but these must be suitably located and properly administered in order to achieve their highest usefulness. The ideal game preserve is a protected area favoring the rapid increase of game within its borders and from which the surplus can readily spread and stock surrounding areas. More game preserves are urgently needed on national forests. The national parks serve as great game preserves in which no hunting is allowed.

Among the requirements of game, the one of prime importance is sufficient palatable food during the winter as well as during the summer. In many regions summer range is ample, but the game is forced by deep snows to migrate to lower levels, where winter range and forage are inadequate, and where suffering and starvation result. This is well exemplified by the elk of the Yellowstone Park region, to which reference has already been made. Especial interest attaches to these elk, as they constitute the only really large herds of big game remaining in the United States, exclusive of Alaska; and they suffer pitifully, many dying from starvation in hard winters. The Izaak Walton League of America is issuing appeals, largely through its journal *Outdoor America*, for funds to be raised by popular subscription and devoted to the purchase of forage-producing lands, to be added to the present inadequate winter refuge in Jackson Hole, Wyoming, where thousands of elk concentrate every winter.

On the other hand, game may become too numerous on certain limited areas whereby the preferred forage plants are destroyed and the number of animals that can be permanently maintained is correspondingly reduced.

The extent of the destruction of game by large predatory animals, mountain lions, wolves, coyotes and bobcats in the western states is not generally realized. Some nature-lovers deplore the systematic killing of predatory animals that prey upon livestock and game and maintain that the balance of nature is thus upset. The hypothetical balance existing at the time of the discovery of America, meaning a stabilized condition under which the numbers of the predatory animals and the game upon which they preyed were about stationary, was, however, long ago completely overturned and can never again be restored.

This is due, as we have seen, to the progressive occupation of the country by civilized man. When we remember that to the onslaughts of predatory animals were added unrestricted killing by men armed with guns, and the driving out of game incident to the clearing of forests and the pasturing of domestic stock, it is not surprising that the game decreased rapidly in numbers. As game decreases the attacks by predatory animals left uncontrolled are concentrated on the survivors, which are thus threatened with complete extermination.

The large predatory mammals—mountain lions and wolves—require for their sustenance animal food in large quantities. Owing to this compelling need, coupled with abundant power to kill, their preference is for large game, as shown by studies of food habits. Hunters on certain game ranges in the west find that stomachs of mountain lions examined usually contain the remains of deer; and it is estimated that on such ranges a single mountain lion probably kills from fifty to one hundred deer each year. In the absence of the lion, sport might have been afforded to fifty to one

hundred hunters who, in killing a deer each, would have benefited by the hunt and would have put to economic use the meat otherwise wantonly lost.

The effective control of the small prairie wolves, or coyotes, is a difficult problem in game protection. They are peculiarly favored by their size, which is small enough to enable them to escape easy detection, and to subsist upon game birds, rodents and other small animals; and yet they are large and powerful enough to constitute a very serious menace as large game and stock killers. Many young deer, calves and sheep especially become their victims.

As nature lovers we are loath to contemplate the destruction of any species, but as practical game conservationists we are forced by the records to the conclusion that the large predatory animals must be reduced to very small numbers if game is to show a satisfactory increase. In various parts of the west, where through systematic efforts most of the large predatory animals have been removed, there has followed a marked increase in deer and other game species.

The success attending recent efforts to restock with deer forested areas in some of the eastern states is doubtless due, in part, to the general absence or scarcity of large predatory animals.

The greatest predatory animal after all, however, is man; and while we can not reduce his numbers, some control must be exercised over his too indiscriminate use of modern firearms, if a sufficient breeding stock of big game is to be maintained. But this does not mean that hunting under proper conditions should be discouraged. The joy of the chase provides wholesome recreation of a kind which can be obtained in no other way, and which perhaps only a hunter can fully appreciate. Some maintain that hunting is cruel, especially as it may bring suffering to the wounded, and urge that predatory animals should be allowed to kill the surplus game. Such advocates are presumably unfamiliar with the frightful methods of predatory animals, which may begin devouring the weak and helpless while still alive, their agony being thus greatly prolonged. It should be remembered that most game animals come to a tragic end. The mortality rate from predatory animals is especially high during the first year. If they escape the hunters, declining vigor eventually increases the danger from carnivores until finally they are pulled down, mauled and killed.

Much information is accumulating concerning all the conditions affecting game, but there is an insistent demand for more exact scientific knowledge to serve as a basis for successful game administration. To maintain the game supply, and at the same time to provide, if possible, fair sport for the increasing number of hunters that may confidently be expected is the problem before us. Fortunately, appreciation of the recreational and economic value of game has become more general during recent years, and the demand more insistent for its protection and increase. Through the efforts of game protective associations and individual conservationists a more enlightened public opinion is resulting in better federal and state laws and measures for their enforcement. Much remains to be done, however, to enlist the interest and local aid of the people everywhere, as without their cooperation laws are ineffective and the protection of game becomes extremely difficult, if not impossible.

It has been the practice in many states to issue hunting licenses for the open season to all comers, with too little regard for the available game supply of any particular area. The hunters may far outnumber the animals hunted within a given section, and under such

conditions, long continued, the extinction of the game is inevitable.

The killing of too many animals may be prevented by adopting a limited-license plan, based on annual estimates of game conditions in each district. This means that the number of big game licenses issued for a given area in one season would depend upon the number of game animals which it has been determined in advance can be spared.

This is proper game administration, but it presents some difficulties in actual practice, for the reason that many persons desiring to hunt may be refused licenses. Another plan for limiting the number of game killed, more uncertain in its results, but sometimes more popular, is to issue licenses to all applicants, limiting the open season, however, to a short time instead of the considerably longer period that might be allowed. The important point is to maintain numbers without the necessity of establishing year-long close seasons, except on game ranges being restocked.

There is an urgent need for a better understanding of the fundamental principles of practical game administration, which may be briefly stated. It should be remembered that the potential rate of increase for any species of animal would, if unchecked, force all others out of existence. A high mortality rate is a biological necessity. Any failure of game to increase in a given section of the country is probably due to one or more of three reasons: (1) There may be insufficient suitable food, water or shelter; (2) too many game animals may be killed by predatory animals or by hunters; or (3) animal diseases, frequently epizootic, may be present.

The number to be maintained on a given area should be the largest that can be supported without reducing the food-producing capacity, due consideration being given to the reasonable demands for grazing of domestic stock and of any other local interests. All surplus should be removed, ordinarily through hunting.

Hunting as a sport attracts men to the forests and mountains, where for a brief period they may escape the artificial life to which most are confined. From such an outing they return to their usual duties, improved mentally and physically, with a broader outlook and with a finer appreciation of natural resources which we can not afford to sacrifice.

SCALE INSECTS[1]

By HAROLD MORRISON

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We hear so very much about the destructiveness of those little creatures known as insects that we are apt to overlook the fact that some of them are very useful to us. Thus, the one family of the scale insects or coccids includes within its numbers more different kinds of insects that are or have been of use to the human race as food or in the arts and industries than does any other corresponding group.

Two forms, referred to in the Bible or by ancient writers such as Pliny, are believed to be scale insects, although there has been some debate as to the particular insect referred to in each case. One of these, living on tamarix trees in the mountains of the Sinai peninsula, is credited with having furnished the manna which supported the Israelites at one period of their migration from Egypt back to the Holy Land. This manna occurs as a thickened, sweetish liquid, somewhat resembling honey, which forms in large hanging droplets on the branches of the tamarix trees as a result of the active feeding of many scale insects. The other insect, whose usefulness has been recognized and described since very early times, is known as the oak kermes and is found on only one certain kind of oak. It supplied to ancient manufacturers a crimson dye which was quite probably the royal purple of the early writers, since this color is at present believed to have been a shade of red rather than the mixture of red and blue which we know to-day by the name purple. Two other related scale insects, living on the roots of grass and other plants, one in Poland, the other in Armenia, also formed important sources of red dye, at least during the Middle Ages and up to the period following the discovery of America by Columbus.

With the conquest of Mexico, soon after 1500, Europeans first became acquainted with that best known of all the useful coccids, the cochineal insect. With its value fully recognized and its place in the highly developed Aztec civilization of that region well established, this insect soon became an important article of commerce for the Spanish traders, so important, indeed, that when the Spanish monopoly in Mexico was broken up after 1800 by the revolution and declaration of independence of that country, the industry of producing the commercial form of the insect for the market was successfully established in the Canary Islands, after attempts to grow it commercially in various parts of Spain and the other sections of the Mediterranean region had proven unsatisfactory.

An interesting sidelight on the history of this insect shows clearly the difficulties that may develop when accurate knowledge of any living form is lacking. This is the story of the attempt to establish its culture in India. Living examples, believed to be of the true cochineal insect, were sent to India from Brazil, were rather widely distributed there, and became well established

[1] Broadcast from Station WRC, Washington, October 29, 1925, under the auspices of the Smithsonian Institution and the direction of Mr. Austin H. Clark.

on previously introduced cactus plants. The development of an industry was encouraged as much as possible, but it was found that some three times the quantity of the East Indian cochineal was required to supply the same amount of dye that a given quantity of the Mexican insects supplied. This, coupled with gradually falling prices for the product, soon caused the complete failure of the industry in India. With our present-day knowledge of the insect and its relatives, we know that these early introductions into India were not true cochineal insects, but were instead one of its wild relatives, smaller in size and so deficient in coloring matter as to doom to failure in advance the attempt to establish a cochineal industry with them.

To-day, due to the tremendous strides that have been made in the production of manufactured or synthetic colors, the coal tar dyes and others, none of the insect dyes can be regarded as commercially important, although a certain quantity of the cochineal insect is still gathered annually in the Canary Islands.

However, there is another scale insect which has not only maintained but has actually greatly increased its commercial importance in recent years. This is the so-called lac insect, from which is obtained the shellac and other commercial lacs, substances having, either in their natural or in their bleached condition, a long list of important industrial uses, taking a part in the manufacture of phonograph records, the preparation of many paints and varnishes, the making of sealing wax and special printing inks, as an insulating material in many kinds of electrical work, for the manufacture of imitation ivory articles, such as toilet articles and poker chips, in some kinds of shoe polish, and so on.

While it has some close relatives on desert plants in the southwestern United States, the true lac insect is a native of India. There it is grown on a number of different kinds of trees, usually as an adjunct to the growth of cultivated field crops. At certain times each year the young insects swarm over the younger branches of the trees on which they live, but soon settle down on these branches in such numbers that when they begin to feed and to give off the protective secretion which very shortly covers them, this secretion eventually so increases in quantity and spreads to such an extent that the individual masses become fused, surrounding each twig, together with the insects feeding on it, with a cylinder of secreted matter, sometimes several inches long, which is the lac. When the enclosed insects are full grown and have finished giving off the lac, the twigs are cut off, giving the stick lac, which, after a rather intricate manufacturing process that results in the elimination of the wood, the bodies of the insects and other organic matter, becomes the highest grade product, shellac, or the lower grade products, button lac, seed lac, garnet lac and others. These are the commercial forms in which the product is shipped to all parts of the world for manufacturing purposes. The total production varies greatly from year to year, according to the demand, but averages around forty million pounds per year, nearly half of which is said to come to the United States.

In this country, scale insects are unquestionably best known as enemies of cultivated plants, shrubs and trees. Due to their intimate association with the plants on which they live, and their generally small size and inconspicuous appearance, they have unwittingly been distributed very widely over the country, and even over the world, by the very people most interested in escaping the damage resulting from their attacks, that

is, by those individuals who were attempting to establish commercial fruit-growing and related industries in new localities.

A brief history of the spread of one of these, the notorious San José scale, may serve to illustrate the way in which an insect may become a pest, and to emphasize the potential dangers lurking in any insect found living on cultivated plants. This insect, probably more than any other single pest, has served to bring home to every one interested in growing plants the great importance of the factor of insect damage in agricultural production.

Although certainly brought to the United States from some other country, probably China, the insect was first discovered in 1880 near the town of San José, in California, whence it spread in the next few years through adjacent local territory and the other Pacific coast states, without attracting much attention, except among those who realized its capacity for damage. It was only after the discovery, more than ten years later, that it had been brought to the eastern part of the country on fruit trees desired for experiments in developing new varieties resistant to the attacks of another insect pest, the plum curculio, and the further discovery that it had quickly become widely distributed and very injurious, due to the introduction of infested nursery trees into many orchards throughout the eastern states, that the insect began to attract the almost universal attention which it ultimately compelled. Subsequently, as the demand for commercial fruit production has arisen in other regions, with the resulting introduction of fruit varieties from the older fruit-growing countries, the insect has appeared in Chile, in South Africa, in Argentina and in northern India. Only the countries of Europe, as a result of the application of stringent prohibitive measures regarding the introduction of plants infested with this insect, and possibly with the assistance of a somewhat less favorable climate, have been successful in avoiding its ravages.

The immediate recognition by the entomologists of the Department of Agriculture of the serious menace to horticulture created by the establishment of the San José scale in the eastern states did result beneficially in one important respect, but at a price which takes toll annually in most sections where fruit is grown commercially. Since the natural enemies of this scale—the tiny parasites and the predatory insects which might devour whole colonies—were obviously too few and too little important to be of service in its control, numerous experiments were undertaken by the department and by the state experiment stations to discover chemical compounds which could be applied to infested trees without injury to them, but with deadly effect on the insects. Of the many which were tried, the few best were developed by further experiments with the aim of greater effectiveness at lower cost, and are, even to-day, being continually worked on and improved as additional knowledge of chemistry and physics and a better acquaintance with the habits of the insect point the way. The net results are that the grower is no longer confronted with the prospect that his orchards may be destroyed in spite of his best efforts to the contrary, while the consumer is able to make his choice from more perfect fruits than were ever available in the past. Besides this, the successful application to other injurious insects of the principle of control by the use of so-called insecticides was greatly stimulated by the results obtained in the fight against the San José scale.

What are scale insects? The scale insects and mealy bugs, or coccids, are

closely related to the plant-lice, and, with these, are familiar annoyances to every one who has ever maintained a garden or raised a fruit tree. All these groups have one characteristic in common, that of obtaining their food from the plant on which they live by inserting a long slender tube in its tissues and sucking up through this the juices of the plant. But otherwise, as they occur in nature, they vary so greatly among themselves, both in appearance and in habits, that it is difficult to believe that they really have that close relationship which scientific studies have shown to exist between them.

Most of the common plant lice are small, naked, soft-bodied insects, about one twelfth to one sixth of an inch in length, with slender legs and more or less pear-shaped bodies colored in various shades of yellow, green, red and brown to black, and often marked or spotted in characteristic patterns. Two pairs of delicate wings may be present, but are more often lacking. Many of these insects live the greater part of their lives hidden away in curiously formed galls on their host plants. The scale insects present a much greater diversity in size and appearance, some, when full grown, appearing no longer than one fiftieth of an inch, while others, such as some of those which are found in tropical regions, reach a length of more than one inch. Some, such as the mealy bugs, have soft bodies concealed and protected by a dense coating of white powdery wax or by a sac of similar material; others are naked but have the outer surface much thickened and hardened to form a protective layer; still others, the true scale insects, these including some of the worst enemies of fruit and shade trees, are tiny, flattened, without legs, and are completely concealed beneath a slightly elevated, scale-like covering made up of cast skins and secretions from the insects' bodies. This covering scale varies greatly in appearance according to the species, some being round, with a tiny conical hump in the center, some oval, some pear-shaped, some resembling the shell of an oyster, and some so very long and slender as to suggest a short piece of thread lying on a leaf. The shape of the tiny insect lying beneath the scale likewise varies much as does that of the scale itself.

These descriptions apply only to the females. The males, where they are known, are small, delicately constructed insects, with long feelers, the usual six insect legs and generally a pair of delicate wings, but with no means of obtaining food, in fact differing so widely from their much larger, fat-bodied, but degenerate female relatives that their relationship would never be suspected without a careful study of their habits.

MEN WHO HAVE EXPERIMENTED ON THEMSELVES

By Professor FRASER HARRIS

LONDON, ENGLAND

THE medical man in the course of his professional duties runs more than the ordinary risks of infection. But he accepts these as incidental to his profession just as the sailor and the soldier accept the risks in theirs.

In the bad old days before the discovery of anti-diphtheritic serum that has reduced the mortality in diphtheria from about 90 per cent. to a very small figure and quite taken the terror from that dreadful disease, the physician ran very great risks in attending a case of diphtheria. Quite often he had to open the wind-pipe to prevent the child being suffocated by the "membrane" that formed over the glottis; and while doing this the child might cough in his face; in a short time he too had diphtheria and not rarely he went home to die.

If "peace hath her victories no less renowned than war," then certainly war has no monopoly of courage.

In the earlier days of the use of the X-rays, before the extent of their tissue-destroying properties was known, several medical men received severe burns from the rays, some had to have a hand or an arm amputated, and one or two lost their lives.

Researchers into medical problems have used their own bodies more frequently than one would think who has not specially noted the fact. Those who work with the microscope have of necessity to use their eyes so long at a time that they are apt to suffer from inflammation of the eyes.

The discoverer of the capillaries—the first man to see the blood moving in these minute tubes—Marcello Malpighi, so strained his eyes that they were painfully inflamed for long periods. He is rightly called "the father of microscopical anatomy," for he made out important minute structures in the skin, lung, spleen and kidney with which his name has ever since been associated.

The outstanding martyr of microscopy is the young Dutchman, Jan van Swammerdam. He worked on the minute structure of the internal organs of insects; and so incessantly for months at a time that not only his eyesight but his general health suffered seriously. Having no artificial light capable of being used with the microscope, which indeed at that date (1660) was but a dissecting lens, he had to work in the direct sunshine and of course only during the day.

"If he desisted at noon," says his biographer, "it was only because the strength of his eyes was too much weakened by the extraordinary efflux of light and the use of microscopes to continue any longer upon such small objects." Swammerdam, who died in 1680, and had graduated doctor of medicine at Paris but never practiced, was the first to describe the minute structure of the may-fly and of the honey bee.

A friend of the author's, a distinguished Scottish pathologist, so injured his eyes with application to the microscope that for many months he could not use them at all. He had been trying to get a glimpse of the excessively transparent parasite of syphilis discovered by a German scientist only a short time before: he verified the discovery.

Laboratory workers have at all times used their own bodies as a ready method

of giving them the materials or data they required as standards. The Dutch microscopist Leeuwenhoek, who was the first to see bacteria, obtained them from material he scraped off his own teeth.

In certain researches small quantities of blood are required from time to time in order to afford a standard of normal color in matching specimens of patients' anemic blood. Those doing this kind of work invariably prick their fingers or ear-lobes for this purpose. Professor J. B. S. Haldane, F.R.S., of Oxford and Birmingham, in the course of researches of this nature, has administered to himself on countless occasions the very poisonous gas, carbon monoxide.

Quite often, too, in the laboratory, supplies of air from the lungs are needed in connection with certain kinds of gas analysis; these are invariably collected by the workers from their own lungs. Here again Professor Haldane has been the leader of a band of workers fired by his enthusiasm. Their work on mine rescue-apparatus has proved to be of the highest value.

The effect of very low barometric pressure is an important subject at the present time, especially for aviators. Very low oxygen pressure is their special trouble.

In order to study the effects on the body of the great diminution of the pressure of oxygen, Professor Barcroft, of Cambridge, and a band of coworkers have lived on the summit of the peak of Teneriffe and on Pike's Peak in Colorado. Here they made observations upon themselves and gained knowledge which has already proved most valuable to aviators and to those exploring very lofty mountains, as for instance Mount Everest.

In order to settle a disputed point about the condition of the blood when one lives in an atmosphere where the pressure (tension) of oxygen is very small, Professor Barcroft volunteered to be shut up in a glass case in which the oxygen pressure had been greatly reduced. At the end of eighteen hours a specimen of his blood was analyzed, and its state corresponded with what he thought it would be from purely theoretical considerations.

To study mountain sickness as thoroughly as possible a physiological observatory was built on Monte Rosa; and here many biologists, by experimenting on themselves, have gained an insight into that distressing result of life at high levels.

A great deal of the physiology of the pulse and heart has been worked out by the physiologists' experiments on themselves. Some years ago a young professor at a Canadian university was found dead in the laboratory with an instrument for recording the movements of the heart still strapped to his chest.

One of the latest triumphs of experimental skill in medical research is the exceedingly delicate instrument, the electrocardiograph, which records photographically the electric currents of the beating heart. This work which led to the diagnosis of unsuspected forms of heart disease has been done almost entirely on the hearts of the physicians themselves.

Students, especially medical students, have at all times willingly allowed themselves to be experimented on by their teachers.

In a rather notable series of observations carried out at the London Hospital by Professor Leonard Hill, F.R.S., eight student volunteers were shut up inside a specially constructed cabinet with a glass side so that the effects of the stagnant, hot atmosphere might be studied. When the oxygen had fallen to about 10 per cent. and the carbon dioxide risen to 4 per cent. and the wet bulb thermometer read 85° F., they began to suffer extreme discomfort. To their astonishment they could not light their cigarettes. Without providing any better

ventilation, the electric fans in the roof were started with the result that the discomfort was very rapidly diminished. The air set in motion had cooled the skin and allowed a refreshing escape of heat therefrom.

Two very interesting control experiments were made on volunteers thus—a student outside the cabinet breathed through a tube air that had come from inside it: he felt no discomfort whatever, because his skin was cool; but, conversely, when one of those inside the cabinet breathed fresh pure air from outside, his uncomfortable sensations were not in any way relieved. All these experiments showed that the discomfort arose not from any chemical state of the air in the cabinet but from its moist heat—a physical condition.

A great deal of our knowledge of digestion has been ascertained through experiments on the human being. The very assiduous and fertile worker in Italy, Lazzaro Spallanzani, at the end of the eighteenth century made many observations on himself in order to ascertain the influence of the gastric and other juices on various kinds of food.

He swallowed bread sewn up in linen bags which after their passage through the body showed that the bread had disappeared—it had therefore been digested and absorbed. He then passed on to experiments which involved the swallowing of meat, bone, tendon and cartilage in small wooden tubes with a number of small holes in them so that the digestive juices could gain access to their contents. On being passed from the body, the condition of the material inside the tubes afforded valuable information about the nature of digestion—a subject concerning which in Spallanzani's day there was very little accurate knowledge. These experiments on himself corroborated those on digestion in the lower animals.

In order to make observations on the acidity of the human gastric juice, Spallanzani did not hesitate to regurgitate from the stomach what it might contain after a longer or shorter time from the last meal.

The American doctor, John R. Young, when preparing data for his graduation thesis at the University of Pennsylvania, made experiments on himself (1800–1803) of the same kind. The title of his thesis is: "An experimental inquiry into the principles of nutrition and the digestive process." He corroborated Spallanzani by showing that normal gastric juice is acid, but he thought the acid was phosphoric, whereas we now know it to be hydrochloric; a fact proved a little later by an Englishman, Dr. Prout.

Apropos of the act of deglutition, two German professors about thirty-five years ago devised a long, tube-like, india-rubber recording instrument which one of them swallowed so as to give a graphic record of what the muscles of the gullet were doing during the process of swallowing first solids and then liquids. They found the exact mechanism was not the same in both cases.

As may readily be supposed, when the object of the investigation was the effect of different kinds of foods upon the human constitution, the investigators had no hesitation in eating all sorts of things in varying quantities.

Again, medical students and laboratory servants volunteered to be experimented upon when Professor Chittenden, of Yale, who was studying the effects on human beings of taking much smaller quantities of meat foods than is usual (what is technically called the minimum protein intake) induced a number of students to submit to live on diminishing amounts of this kind of food until the quantity was only one third of that usually taken.

One remembers the fasting men of the nineties, the professional Succi, the Italian, and the amateur, Dr. Tanner, M.P., the Irishman. Each fasted for at least forty days. Dr. Tanner is alleged to have had no solid food but only water

during his ordeal; the professional had an "elixir" of secret composition to sustain him. Succi allowed a committee of physiologists to investigate his case, and some important facts in biochemistry were thereby obtained.

One Dutch physiologist has subsisted for some days on nothing but oil and wine in order that he might study the diseased state acidosis which is induced by that kind of diet: a good deal of light, very much needed at the time, was thrown on that condition, which may also occur as the result of underfeeding and other causes.

Allied to researches on food are those which involve muscular work being done so that the effects of food or some other variable on the output of energy may be studied. Physiologists have devised several forms of work-measurer (ergometer) one of which is a bicycle-like machine on which the experimenter sits and does (external) work, the amount of which is registered on a dial.

But long before the days of geared bicycles, two foreign physiological chemists, Fick and Wislicenus, desiring to study the effect of diet on bodily work, climbed one of the Alpine peaks—the Faulhorn—in order to accomplish a measurable output of energy on a known amount of certain foods.

The work done was that of raising their bodies through the height of the mountain; in fact they "gat them up into the high mountain" to ascertain the relations of food to bodily work under definite conditions.

The most spectacular case of men experimenting on themselves in this line of work is that of two American physiologists, Atwater and Benedict, who constructed what is called a respiration-cabinet, a small heat-proof room in which they could do measurable work on the bicycle and where all their heat was absorbed and measured. In this way, they ascertained very accurately what became of the potential energy of their food.

Those who study the action of all kinds of new drugs—the pharmacologists—have never hesitated to test on their own persons the action of the many substances which they have to investigate. One of the earliest examples of this sort of thing was the foreign physiologist Purkinje, famous in biology for having coined the word "protoplasm." On himself he tried the action of all the following—belladonna, camphor, opium, stramonium and turpentine; and he died in his bed!

But medical men have not hesitated to give themselves certain diseases in order that some disputed points about these might be cleared up.

One of the greatest English naturalists and surgeons, John Hunter, deliberately inoculated himself with the poison of venereal disease. Hunter wished to clear up the confusion which existed in his day regarding syphilis and gonorrhea. His self-inoculation proved only too successful from a purely scientific point of view, for in due time he developed the hard chancre of true spyhilis, ever since called "Hunterian."

There is now no doubt that a great deal of Hunter's subsequent ill-health and fatal illness must be directly traced to his voluntary martyrdom in the interests of exact medical knowledge.

One of the best known cases is that of the son of the late Sir Patrick Manson, who allowed himself to be inoculated with malaria in London and proved that climate as such has nothing to do with that disease, but that it is communicated solely by infected mosquitoes. Young Manson was bitten by some malaria-carrying mosquitoes; and in due time developed typical malaria in England. By appropriate treatment he recovered from this disease only to die a few years later by being accidentally shot.

As long ago as 1842, when the cause of the serious skin disease Favus or "ringworm" was not precisely known, a German doctor, Robert Remak, inoculated himself with a fungus which he

suspected of being the one to blame. He developed typical ringworm and so settled the point in doubt: he named the fungus after the specialist on skin diseases, Schönlein, with whom he had been studying in Berlin (Achorion Schönleinii).

Much nearer our own day, in 1883, Pasteur, who had just discovered the now celebrated cure for hydrophobia or rabies, was quite prepared to inoculate himself with that frightful disease and subsequently inject himself with the curative attenuated virus. Luckily, just as Pasteur was about to do this, the chance of snatching from death, as he phrased it, a little Alsatian boy bitten by a mad dog some days before presented itself, and so relieved him from this operation on himself. Thus Joseph Meister was inoculated and lived.

A most distinguished neurologist, happily still living, cut in his own arm one of the nerves of his hand in order to study the exact order of the return of the different kinds of sensation with which the hand is endowed. The information required, involving as it did observation by an educated mind, was very difficult to gather from hospital patients, and so Dr. ——— cut his own ulnar nerve at the elbow and observed the phenomena for himself. Full restoration of all the sensations was not brought about for one year.

As one might suppose, the effects of anesthetics were nearly all tried by the experimenter on himself before being made public. Thus Humphry Davy, in 1880, inhaled nitrous oxide or "laughing gas" on many occasions before he ventured to announce the new anesthetic. When he did, he suggested its use in exactly the kind of case in which it has proved so useful—"surgical operations in which no great effusion of blood takes place," namely, in dentistry.

The experiments of Sir James Simpson with chloroform on himself, his assistants and relatives are perhaps the most celebrated of auto-experimentation in the history of medicine. Miss Simpson, in her vivid and interesting life of her father, says that he always tried a new drug on himself first; and that on one occasion he was insensible for two hours from the results of taking some compound of more or less unknown composition.

Simpson tried a great many anesthetics before chloroform was finally adopted.

Dr. George Keith and Dr. Matthews Duncan were faithful henchmen in sharing with their master all the risks of the unfamiliar properties of chloroform.

It was in the winter of 1847 that Simpson, Keith and Duncan would sometimes be all under the table at one time; and there was no page-boy to loosen their cravats.

We are told: "These experiments were performed after the long day's toil was over at late night or early morn." Sir James's niece, Miss Petrie—the first woman to be put under the influence of chloroform—was boldly experimented on in the interests of the cause.

Clark, the butler, too, not only experimented on himself but on one occasion gave chloroform to the cook. His method of administering it was evidently calculated to insure its popularity, for he mixed it in such "a richt guid willie-waught" of champagne that that good lady was prostrated in a few seconds on the kitchen floor. He had to call in "his master's voice" to restore the most important member of the household to the consciousness of the light of common day.

The butler took a great interest in the chloroform investigations; he watched his master trying new and unfamiliar substances; but as time went on his belief in the superiority of chloroform increased, and on one occasion he adjured Professor Simpson with solicitude and familiarity:

"Stick to the Chlory, Sir James, stick to the chlory!"

THE MACHINE AND MANAGEMENT

By Professor FRANK T. CARLTON
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No competent engineer would build a bridge or design a locomotive without careful and painstaking consideration of stresses and strains, of the forces of gravitation, of adhesion and cohesion, of factors of safety and of a multitude of other fundamental factors. To do otherwise would be to invite disaster. Likewise, if it runs counter to fundamental social forces, no plan for evolving a better social and industrial edifice has a reasonable chance for success. Experiments in industrial management and personnel administration constitute investigations into the complexities and perplexities of social science or of human engineering. Obviously, the determination of a rational labor policy involves the consideration of complicated and delicate forces. Nevertheless, nearly every person feels entirely competent to determine offhand labor policies, political programs and social platforms with only the aid of preconceived notions and inherited beliefs. Many are the blind attempts which are being made to solve industrial problems. In most cases, the experiments remind one of the man ignorant of the automobile who tries to eliminate engine trouble by acting along the lines suggested by a series of haphazard guesses as to the difficulty; but ignorant social experimentation is often costly. As a rule when attempts are made to analyze the fundamental causes of industrial strife, the assumption is made that the conflict is clearly one in which employers and investors are lined up in antagonism to the employees and wage receivers. The elements of friction are assumed without further consideration to be due primarily to differences in interests and points of view of employers and employees. The socialists and the conservatives have accepted these *a priori* premises. If this view be accurate, the solution evidently must be found in attempting to discover common interests in industrial peace and in minimizing points of disagreement; but it may be necessary to delve more deeply into the intricacies of human psychology and of racial inheritance.

Recently these other aspects of the problem have begun to win a hearing. Bernard Shaw insists that civilization is too complex for the intellect of short-lived human beings to comprehend and intelligently to direct and control. Civilization is likely to be ground to pieces by forces of its own generation. Lothrop Stoddard has painted a picture of the menacing group of undermen. Thorstein Veblen has philosophized about the effect upon man of the machine process. Arthur Pound has attracted much attention by his interesting analysis of the Iron Man and its influence upon Flesh-and-Blood men. Mrs. Bruere has focussed the attention upon the urge to spring planting which the uncontrolled machine process insists must be inhibited. And Professor J. M. Clark has outlined the "Empire of the Machine"—a realm in which human beings have accepted the rank of servants or the status of a subordinate class. The new industrial fabric is considered to be a web entangling the human race. The latter writer suggests "that the unrest

of labor is not a fight for wages and hours merely, but more fundamentally a revolt against the bald fact of servitude, and that it is at bottom servitude to the machine rather than to man." Consequently it can not be cured by high wages, improved working environment, shop committees or personnel management—helpful as these may be. From this point of view, the industrial struggle is either one connected with the growing pains of a society which is being depersonalized and becoming machine-dominated, or it is the death struggle of the old society of primitive, ancient and medieval craftsmen who knew not the machine.

If the friction in industry to-day may be attributed in no small degree to the difficulties of adapting man—an extraordinary complex of instinctive impulses—to the regularity, routine and monotony of the work of a machine tender or helper, if it be a conflict due to the pressure of machine industry and, therefore, to the necessity of adapting a roving and restless people to the requirements of routine and repetitive industry, a quite different task confronts human society. If the second concept be fairly accurate, the industrial conflict is in part a struggle of human beings against a machine or technological system which they have built up step by step and which now ominously threatens to bring down upon their heads the edifice which is called civilization. Must man be adapted to the machine, or is it feasible to make the machine process the servant of civilized society? The second aspect of the problem is now to be placed under consideration.

The primitive man knew little or nothing of punctuality and routine. He hunted and fought at irregular intervals. He took little heed of the morrow; work was not on his short list of virtues. The primitive, ancient or medieval man was little bothered by clocks, cost accounting, efficiency, conservation or machines of any sort. Uncertainty, the alternation of famine and plenty, leisure to-day and strenuous exertion to-morrow, ennui of idleness to-day and to-morrow the climax of a thrilling hunt were typical of the long ages of the primitive world in which the great fundamental characteristics of human nature were molded. The primitive man constantly faced the world of nature. On the other hand, relative certainty, the doing of the same things to-day and to-morrow that were done on many yesterdays, a humdrum level of a reasonable standard of living, unless the job is lost, is to-day's portion. The great uncertainties of to-day in the normal times of peace are the prosaic and unheroic ones of unemployment and sickness. The environment of the typical city and shop worker is man-made—paved streets, rented houses, municipal water and lighting, commercialized amusements, the artificial thrill of the melodrama on stage and movie screen. The discipline of the machine age runs counter to deep-seated impulses, social habits and mores. Unrest seems inevitable. The worship of regular work, of work for work's sake, is a product of an age of machinery and efficiency; it is a new cult. Irregularity and immorality are being tied together. The ultra-modern concept that business is the end and aim of industrial activity is machine-made. From the point of view of human beings, business for the sake of business is a futile slogan. Business should be carried on for the sake of better and happier men, women and children, not for more and more machines and investments.

Within a comparatively short space of time, the machine has gradually assumed a dominant position in the world. If to-day the machine process ceases to function, man is helpless. Man's dependency

in the centuries preceding the nineteenth was upon natural forces—climate, moisture, wind, flood, drought, change of seasons and the like. Gradually, but inexorably, the machine and its friend fellow-worker, science, have conquered the forces of nature. Only occasionally when these forces get temporarily out of grasp of the machine and of science do the old familiar foes of mankind become menacing.

But, as imperceptibly and as inevitably, mankind has passed under the velvet-covered yoke of the bounty-giving clan of the machine. We live where the necessities of the machine dictate—smoky and dingy Pittsburgh, the repulsive oil fields of Wyoming, the desolate sand prairies of Gary, the tenements of the East Side of New York City. The vast immigration of recent decades is in direct response to the call of the machine. We get up in the morning, continue at work and return home in accord with the will and pleasure of the amalgamated association of machines. Man is becoming —yea, is—the valet of the machine. The leading economists and students of business affairs are studying business cycles in order to appease the wrath of the "God of continuous utilization."

By inheritance, mankind is fitted for irregular and seasonal work. Men were hunters, fishermen, shepherds and agriculturists long before the industrial age appeared above the horizon. Not until the nineteenth century was any considerable group of men pried loose from the soil and tied to jobs in shops and office. Not until after the dawn of the nineteenth century were persistent performance and routine exalted to the ranks of major virtues among the great masses of mankind. The machine process is responsible for the respect shown the dictum "that wanderlust and productivity have become mutually exclusive." Business experts, engineers, bankers and economists bowing to the dictates of the machine process are much concerned with the reduction of seasonal and cyclical variations in business. On the other hand, the biological and psychological inheritance of mankind points toward the desirability of seasonal fluctuations and variety in industry.

If, from the engineer's point of view, workers are to be adjusted to the requirements of a highly organized and efficient industrial order, regularity and routine must become second nature. The wanderlust, "the call to spring planting," the frequent trips to forest and stream must be inhibited. Jungle and unutilized river banks must give way to the stern demand for complete utilization, and the ideal man of the new order will become a sort of animated machine. The increasing prevalence of the vacation is a gracious concession on the part of the clan of machines to the biological background of capricious and untamed men. If, on the other hand, industry be required to yield precedence to men, seasonal fluctuations in industry will remain, industries will be dovetailed, and regular industry will be encouraged to become irregular so as to cooperate with seasonal industries. More emphasis will be placed upon the development of normal human beings.

Is there hope for man? Can it reasonably be anticipated that he will dominate the machine? Or must he be content to continue subordinate to the great machine clan? Is the new art and science of personnel management to aid man to dominate the machine, or will it merely point the way toward a more rapid and peaceful acceptance of man as the machine tender? For years, the conscious and unconscious program has been that of adapting man to the requirements of machinery and technological processes. Only, after we have met serious obstacles, after civilization is in

danger of being broken between the discordant requirements of machines and the inherited tendencies of human beings, and after machinery has obtained an almost impregnable footing, has the race of men started upon the study of social forces, of human interrelationships, and of the relation of men to machines. Can machinery and science become tools to produce commodities and services for men instead of for the further advancement of the machine age and the subordination of men to the requirements of the machine?

If man is to be domesticated to the machine, what type of man will result? If the Iron Man is to win in the struggle with the Flesh-and-Blood Man, will the fittest to survive be the docile and sluggish machine tender, the mechanical engineer, the business man of the Babbitt type? Are the men of initiative who rebel against monotonous work and red-tape, who refuse to worship with the aggressive group of efficiency experts and home town boosters, to be pushed to the wall as machine industry moves forward triumphantly to conquer new fields? The famous humanitarian group in pre-Civil War New England went out in a blaze of intellectual fireworks before the onward tread of the youthful factory age. Is this a portent of what is to happen wherever the machine extends its sway? Is the human intellect to become "machinized"? If so, if the machine be the victor, if the requirements of the machine process are to determine the characteristics of the working group, then the problems of the industrial world are those of adapting mankind possessed of certain inherited characteristics to this new machine-dominated world. However, this seems to run counter to the implications of democracy. Universal education and the free school system are supposed to place emphasis upon traits which are very different from the docility required of machine tenders. A good citizen in a democracy is not a docile, unthinking, machine-like creature.

Business as it is carried on to-day is favorable to machines rather than to men. Business is carried on in order to get more business. Savings are poured into industry in order that more machines and capital may be produced. Capital begets Capital. The great Ford business has had a high birth-rate. Capital valued at approximately one hundred thousand dollars has multiplied with little or no immigration or influx of dollars from outside investors until it is numbered by the hundred millions. This has taken place within a score of years. The annals of human birth-rates exhibit no parallels. And, in this enormous and youthful machine plant or organism, mere human workers must obey without questioning the dictates of the engineers and business experts who act as the interpreters or high priests of business efficiency. Indeed, what is business efficiency to-day except conformity to the dictates of the amalgamated order of machines? The "foolproof" machine—with the orderly processes of which the human being can only with difficulty interfere—is the high-water mark of machine technic.

The corporation is the acme of impersonality. Up to date the large corporation constitutes the finest token of machine domination and of human subordination. It is the crest of the wave which is submerging the old order of men and which is making us slaves of the machine process. Men may come and men may go as managers, owners or wage-workers without in the least affecting the even tenor of the progress of the corporation. The modern trust company in its advertising boasts of its superiority over the human or natural person.

The preeminence of the machine is making the old life of semi-isolation with its emphasis upon individual and family

traits chiefly a matter of historical significance. Street life, factory life with its groups of workers engaged in common tasks, the educational system with its large classes and units, common and standardized amusements, the growth of club and fraternity life—all tend to mark the members of industrial society with a similar stamp. Even the family, that stronghold of individualism, is seeing its influence upon child life gradually weakened. Medical clinics, hospitals, kindergartens, supervised public playgrounds, the public schools, the popular amusement house, the automobile and the radio are all reaching out for functions which were the monopoly of the old-fashioned home of the isolated pioneer. And, furthermore, the working-away-from-home mother and the working-away-from-home children were unknown in the case of the traditional American home.

Even in the educational world the struggle is on more or less consciously between those who advocate that the youth should be educated so as to make for initiative and thoughtful resourcefulness and those who would mold the youth to fit into the modern machine process and business technology as carefully drilled specialists who may readily become excellent valets of the corporation and the machine. In the world of machines, standardization is a word and process which is given high rank. Our school system has succumbed to the pressure of machine requirements. Pupils are being standardized and regimented in an unprecedented manner. The ideals of education are becoming deeply colored by the machine process. To turn the machine into a servant of man may be only the hope of a Utopian. Perhaps science can only be the friend and coworker of the machine. Nevertheless, if there be such a science as social, its function is to enable man to regain premiership in the realm of industrial institutions.

Fortunately, there is plausibility in the assertion that the evils of the machine process are due in a large measure to the incomplete expansion of the sphere of the machine, that industrial friction to-day is in a large measure a growing pain which will pass away with more complete utilization of the machine. If the present considerable restriction of immigration into the United States is continued for a few years, a notable laboratory experiment in social science may be worked out. Scarcity of workers and high wages furnish an incentive to the wide-awake enterpriser to utilize more and more machinery. While the industrial progress of the United States has been hastened and its direction modified by the great influx of immigration during the last decades of the nineteenth century and the opening years of the twentieth, restriction of immigration will doubtless hasten further use of automatic machinery. The Iron Man may take the place of the semi-automatic worker. The fear that machinery necessarily calls for morons and other low-grade workers may prove to be unfounded. Adequate development of machinery may lead to the displacement of morons and the lower grades of unskilled workers by automatic machinery with skilful operatives and repairmen. The "empire of the machine" may prove to be in actuality the empire of the skilled worker, the trained technician and the cultured human being.

The application of scientific methods will elevate many a task from the status of distasteful drudgery to that of a skilful and attractive job. This tendency is thrown into clear relief when a contrast is drawn between the operator of a steam shovel and the wielder of the old hand shovel, between the washing of dirty clothes by bending over the washboard and by means of the electric washer, or when a comparison is made of the engineer of a central heating plant and the

fireman in a small flat. Harness a job to machinery, natural forces and scientific knowledge, and the ugliness is often sloughed off. Indeed, a new dignity attaches to such work. A large supply of unskilled workers helps to tie the workers to the machine; the latter sets the pace. Limit the supply of unskilled workers and the machine is requisitioned to do new tasks. The machine then becomes the tool of the worker.

Scarcity often gives distinction; it is an element in value. It is not unreasonable to argue that with increasing scarcity of workers willing and eager to perform menial and unlovely tasks, may come a higher esteem for those who are willing to perform necessary but disagreeable tasks. In a large city, the collection of garbage is an essential occupation; a scarcity of garbage collectors may lead to the ascription of more merit and the payment of higher wages to those who perform such tasks.

It is not entirely unreasonable to assume that civilization is only on the threshold of the age of machinery. The machine is introduced very slowly in countries where wages are low. Better training on one hand for the coming generation and a decrease in the number of poorly trained or unskilled may lead in the next few decades to an unprecedented increase in capital and in output, and also in dependence upon scientific methods. Machinery may become in truth the servant of an educated mankind. May it not be that the evils in our factories and workshops which are attributed to machinery are in reality the result of the partial use of machinery? Are not a great multitude of routine machine feeders and tenders doing work which the machine can and will perform if machine feeders become scarce and able to obtain high wages? Imperfectly developed machinery makes man the slave of the machine; but a fully developed machine age emancipates man from drudgery and unskilled work.

The skilled worker may become the normal type of American wage earner; and opportunities for high-grade positions may in the future depend less upon a great supply of unskilled workers than upon an adequate supply of capital. The fully developed Iron Man can be made the servant of man; the Iron Man may not necessarily be an evil spirit condemning vast hordes of humans to routine and drudgery. A notable increase in scientific and purposeful education may place mankind on the threshold of new and alluring possibilities of productivity, of social betterment and of industrial peace. The problem of achieving industrial peace, let it be repeated, is one in social mechanics; and it is not Utopian to urge that the solution can be ascertained.

STUDYING THE SUN IN CHILE[1]

By L. B. ALDRICH

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION

FOR the past twenty-five years the Astrophysical Observatory of the Smithsonian Institution has been engaged in a study of the quality and intensity of the light and heat given off by the sun. Here upon the earth we live at the bottom of a great sea of air. The sun's rays which reach us after passing through the air are very different from those which were actually emitted by the sun. The various constituents of the air—the water vapor, the carbon dioxide, the oxygen, the dust particles and so on—serve to scatter, reflect and absorb the rays in varying amounts and permit only a much altered fraction of the original rays to reach us. Man is not yet able, by balloon, by aeroplane or by any other means, to investigate directly the solar radiation before it has undergone these alterations in the atmosphere. All we can do is to try to measure accurately the rays received here and correct them as best we can for the losses they have suffered.

The problem is an exceedingly complicated one. It has been necessary to evolve special methods and special instruments of great delicacy. The work, first started about the year 1900 under former Secretary Langley, whose name stands so high in the world of aviation, and continued since his death under the able leadership of Dr. C. G. Abbot, showed such promise of valuable results that it has been carried on with increasing vigor all these years. Observations were begun here in Washington, but it was soon evident that reliable work could not be expected in so impure an atmosphere. Expeditions were made from time to time to Mt. Wilson and Mt. Whitney in California, to Hump Mountain in North Carolina, to Bassour, Algeria, and to other places, in order to obtain observations under better sky conditions. Careful investigation was made to find the proper location for a long series of solar observations under the best available atmospheric conditions. Four things were required of the atmosphere: First, that it be as pure as possible, free from dust, smoke and other impurities; second, that it be as dry as possible, because even a small amount of water vapor absorbs great quantities of solar radiation; third, that it be as rare as possible—which condition could be satisfied by choosing a high altitude; fourth, that it be as uniform and unchanging as possible. The place chosen as best meeting these requirements was Mount Montezuma, on the western slope of the Andes Mountains in northern Chile. So far as the institution is aware there is no place in all the world more favorable for its solar observations than this mountain top in Chile. In 1919 a station was established there to make daily observations of the solar light and heat.

In these observations it is important that the instruments be maintained at a constant temperature. To this end they are mounted securely in the interior of a cave dug into the mountainside. A mirror arrangement reflects the sun's beam into the cave where it passes

[1] Broadcasted from Station WRC, Washington, November 19, 1925; one of the Smithsonian series of radio talks arranged by Mr. Austin H. Clark.

through a prism made of special glass. The effect of this prism is to break up the beam into a spectrum showing its component parts. The spectrum thus produced is passed slowly across a very delicate instrument called the bolometer. This instrument is essentially an electrical thermometer so sensitive that it will measure a change of temperature as small as one millionth of one degree. The bolometer measures and records upon a photographic plate the intensity of each wavelength in the whole spectrum, from the ultra-violet through the visible light and including the infra-red or invisible heat rays. Simultaneously with the taking of this bolometer record, the observers are busy with other instruments. One of these instruments measures in calories the total radiation being received at the station. Another measures the brightness of the sky in a definite zone around the sun. These instruments were also designed and built at the Smithsonian Institution. A fourth instrument measures the altitude of the sun, from which we can determine the length of the air path through which the rays came.

Having taken at least five sets of observations at intervals during the morning, the observers must develop, wash and dry the photographic plate which contains the bolometer record. Then with another instrument of special design the plate is carefully measured. After several hours of computing the reduction of the day's observations is completed. So improved are the instruments and methods, however, that one man can take and reduce a complete set of observations in one day, whereas formerly two men would require at least a week to obtain a similar result. The final result of a day's work is a number called the solar constant. It represents in calories the total radiation from the sun which would reach the earth per unit of surface if there were no atmosphere.

Unfortunately for the men who do the observing, the most favorable place for solar study is otherwise most unattractive and desolate. A more dreary monotony both of landscape and climate would be difficult to find.

In January, 1923, it became my duty to take charge of this station and to occupy it for two and one half years. Imagine, if you will, this mountain top, 10,000 feet above sea level, in the heart of the great desert of Atacama. This desert, over whose surface is scattered the peculiar deposit which yields the widely known and valuable nitrates of Chile, is often referred to as the most desolate desert in existence. In this desert are found rich deposits of copper and other metals. It is a curious fact of nature that here where nothing of value is found above ground an unusual abundance is found below the ground. To reach our station one rides all day in a curious narrow gauge train winding its way up to the gradual slope from the port of Antofagasta. All day long as far as one can see on either side there is no sign of life, neither animal nor vegetable. The sun shines with astonishing brightness from a cloudless sky. Occasionally the train stops at a nitrate officina or shipping point for the crude nitrate gathered from the soil. At nightfall we reach Calama, an old Indian village and probably a southern outpost of the old Inca civilization. Here we disembark and drive our auto out into the desert, winding upward to the top of Montezuma. In this desolation, with no living thing, plant or animal within a radius of twelve miles, the Smithsonian Institution has its solar station. Here on the northern slope the great cave for instruments has been dug and a small shop and house built for the observers. Here, with his small family and one

assistant, the observer lives, Robinson Crusoe-like, in primitive fashion save for such comforts as he can install with his own hands. All supplies including water he must bring by auto from Calama. Here he must work out his own problems, surrounded by a maximum of monotony and desolation. The view on all sides is an unchanging, rolling desert broken only by the grandeur of the high Andes in the background to the east. Over twenty of these snowcapped peaks are visible, one of them a smouldering volcano whose smoke we could occasionally see. The weather is even more monotonous than the view, for each day is a repetition of the previous day. A cloud in the sky is very rare—rain, even of a few drops, is almost unknown. The sun shines with a brightness we never experience here. The air is so dry that one's lips and hands are chronically chapped. Each day is warm, each night is cold, often down below freezing. Each morning is calm, each afternoon there is a strong westerly wind subsiding at sunset.

One would naturally wonder how life could be made bearable in such environment. We found it not only bearable but full of interest. There were even advantages we do not have here. There were no flies, no insects, nor unpleasant creatures of any kind. We were free from the annoyance of disagreeable neighbors and lived our lives as we chose, unhampered by the conventions and obligations of city life. The official work of the observatory of course occupied the larger portion of our time. Our spare time was devoted to improving our living conditions. Many a thrill of pleasure we experienced as we settled down to enjoy some comfort we had made ourselves. One innovation in particular pleased us. We brought down with us an ordinary farm windmill, mounted it at the very top of the mountain and attached an electric generator to it. Thus we harnessed the daily afternoon wind, charging storage batteries which furnished electric light and power sufficient for all the needs of the station. That windmill is still faithfully performing its duty of supplying the comforts of electricity to my successor in Chile. We were fortunate in having also such luxuries as a piano, phonograph and many good books, and since my return a radio has been installed with which it is hoped our observers will be able to listen in on North American programs. Some drawbacks there were in the desert life, more particularly in the lack of variety in food and in the lack of proper medical and dental attention. But taken all in all, we look back upon our desert life as full of interest. Our frequent contacts with the inhabitants of Calama, mostly Bolivian and Chilean Indians, picturesquely dressed in homespun clothes, the women in huge gathered skirts of bright colors (we were authoritatively told their skirts measured ten yards around the bottom), the men wearing sashes and gay-colored ponchos, the droves of llamas bringing down the llareta, a peat-like moss from the high Andes universally used for fuel, the scrupulous politeness of the natives, the curious mixture of quaint Spanish and Indian dialect they spoke—all these things were impressed on our memories.

I must not fail to mention the greatest asset we found there. Mr. and Mrs. Drummond, a typical Scotch couple who have lived for many years in the quaint little village of Calama, took a great and intelligent interest in our work. They did all in their power, in innumerable ways both great and small, to add to the comfort of the observers as well as to further their work—and all without expectation of reward. To find such friends in such a place did more to encourage us than any other factor.

We may well ask, of what value is this study of the sun in such a place? In addition to the purely scientific viewpoint—of adding to our knowledge of solar radiation—there is another factor of importance to us all. The so-called solar constant is shown by our observations to be not a constant but to fluctuate irregularly from day to day through a small range. It is surely reasonable to assume that this daily variation must have some effect, however remote and however complicated the process, upon the weather here upon the earth. The promise which our work holds, namely, of adding a new element to the present means of forecasting weather, is of interest to all. The Weather Service of the Argentine government has for several years used our Montezuma results, which are cabled daily to Buenos Aires, and finds them of value in improving their weather forecasts. In recent months the Montezuma values have also been cabled in code to the Smithsonian Institution. They are being used by Mr. H. H. Clayton, a prominent meteorologist, in a study of the correlation between our solar values and the known weather conditions about New York. This study also has already made encouraging progress.

In so complicated a research, even the best of skies, of instruments and of observers fail to produce perfect results. We are constantly on the alert to improve them. But the biggest aid to better results would be the establishment of a series of stations in widely separated places, under the best sky conditions, all carrying on the same line of observations. To this end, the Smithsonian has a second station at Table Mountain in southern California. And but three weeks ago our director, Dr. Abbot, left on a six months' tour of the eastern hemisphere in search of the best location for a third station. This third station is made possible through the co-operation of the National Geographic Society. With these three stations, one in the desert of northern Chile, one in southern California and one in the best location to be found in Asia or Africa, we hope and confidently believe the Smithsonian Institution will produce results of great value to mankind.

WHY DON'T WE FLY?

By Dr. EDWIN G. DEXTER

FOUR or five years ago it was confidently predicted that by this time aeroplanes would be as common as flivvers; that we should be commuting by the air route and taking our afternoon recreation in clouds other than those of dust. But are we? And if we are not, why not?

Mechanically, aeronautics have advanced according to prediction. The continent has been spanned with the sun. Our triad of planes has rounded the globe in its triumphal march. Our mail is going from coast to coast on a thirty-hour service. Commercial air routes are in successful operation all over Europe and in some portions of our own country with a hazard to life and limb not much in excess of that of terrestrial travel. But after all, the thing has not taken hold. Why is it?

I have yet to see discussed in print what seems to me to be the real cause. The mechanical difficulties can be surmounted, those of the plane itself, those of landing fields—they are easy. But how about making over in a single generation, or even in many generations, a terrestrial animal into a celestial being?

Since the commencement of organic evolution, we and our ancestors, nobody knows how many generations of them, have lived on solid earth and we feel safe and at ease there and nowhere else. We are accustomed to travel there. It is true that from the ox-cart to the automobile the rapidity of terrestrial travel has been increased many fold, but the change is after all quantitative and not qualitative. Even though the first time we made fifty miles an hour in an automobile we were a little worried, time cures that and it is not long before we accept it with equanimity, because we are just as near terra firma as we were in our buggy days. But it is very different a few thousand feet up. I know, because I have tried it.

For some months I was in such relation to a government department as to have air service at my disposal whenever needed for official duties. I was up a dozen times at least, and perhaps twice that number. I didn't keep track. I pretended that I enjoyed every minute in the air, but I didn't. I kept on to see if I wouldn't enjoy it after a while, but I didn't; and when my wife, who had by the way never made any objection to my flying, asked me if I didn't think my obligations to the family would justify me in accepting a little slower and safer method of transportation, I was glad of the excuse to stop flying. I have never been up since, and I am never going up again unless it be in line of duty.

Don't gather from what I have said that I was ever frightened while in the air. I was not. But I never experienced the restful feeling there that I enjoy. The real difficulty with me, however, and what I feel is going to be the difficulty with the air commuter if he ever comes, is not while in the air, but while out of the air. I think I never decided that I would make a flight the next day and enjoyed the rest of the evening. I never tried a thermometer or a blood pressure machine at such times, but I believe if I had every record would have been abnormal.

I remember twenty-five years or more

ago when living on the western plains that I had two ponies, one of which I always rode when I tried, while the other I sometimes did. The latter was named Rattlesnake. I tried to ride them alternate days. I enjoyed every second of the time after I got one foot into Rattlesnake's stirrup, whether I stayed on or not, and the seconds went fast. On alternate evenings I had nothing on my mind. Those were the evenings after I had ridden Rattlesnake. After a while the thing got on my nerves, and Rattlesnake got lost. I tried every possible way to find him (which I was sure would not succeed) and let all my friends believe that I was heartbroken at losing him.

And mark my word, the first commuter by the air route, yes, and the second and the third, and nine out of ten if there ever be that many, will let his aeroplane get lost or out of running condition within three months. He will probably seem to be just as sorry about it as I seemed to be at the loss of my pony, while in reality he will be just as sorry as I was and no more. But he will travel the land route again just the same. You can't make a man feel at home as a bird.

I do not mean that aeroplanes have no place with non-professional flyers. Probably four people out of five can get up courage enough to make a flight. They will lord it over the rest who have not, congratulate themselves on their courage, tell their friends that they liked it, and make up their minds down deep in their hearts that they will never go again. The other one is obsessed with the "fear of the abyss" and you couldn't hire him to go up under any circumstances. I have personally known a good many aviators, but have yet to find one who is not looking forward to the time when he can give up flying. There probably are some who do not feel that way, but I have failed to meet them. Where are the pioneer flyers whose obituaries you have not read? They are on solid earth, most of them, and you couldn't pry them off.

And the worst of it is—if my thesis be correct that the insurmountable obstacle to popular flying is psychological—that there is no solution to the difficulty. The hazard of flying, though comparatively slight, is sufficiently great to blot out the flying strain. Doubtless the aviator who sticks to it for any length of time possesses an inherent tendency which if perpetuated would develop a breed of flyers. But he is the very man that aviation annihilates sooner or later, without perpetuating the tendency. Doubtless, too, sexual selection enters in. It seems probable to me that the girl who felt it would be just as easy to fall in love with a broker of her acquaintance as with a lieutenant of the air service, would, for prudential reasons, give the broker the inside track, though this might not be true for the extremely romantic type.

We shall perhaps always find men approximately of the Lieutenant Maughn type to man our air service, and there will be enough of us who haven't yet experienced the "ten foot feeling" which comes from having braved the air at least once, to maintain a fairly prosperous commercial aviation. But don't buy stock in the Aerial Flivver Company. You will lose if you do.

A NEW MECHANICAL PHONOGRAPH

By HENRY C. HARRISON

MEMBER OF THE TECHNICAL STAFF OF THE BELL TELEPHONE LABORATORIES

Sound is probably the most powerful means of conveying emotion. With all due respect to the printed page, sound is probably the most common means of conveying ideas. Furthermore, sound is one of our most useful sources of information, as witness the automobilist listening to the engine or the doctor listening at the chest of his patient.

To make the fullest use of all these experiences, it is of great advantage to be able to reproduce sounds at will. Up to a generation ago, the only method of recording sound was by means of various alphabets and systems of musical notation, the reproduction depending wholly upon the skill of readers or musicians. A first step towards meeting the need for a better and more direct method of recording and reproducing was made in 1877 by Thomas A. Edison's invention of the phonograph. During the nearly fifty years intervening between this first invention and the present phonograph a great deal of effort was put forth to improve reproduction. This effort for the most part took the form of trying multiplied experiments, results being judged by ear. Even in the hands of very able men this method is quite limited in what it can achieve, especially when used on a complex problem such as the phonograph where there are literally millions of possible combinations of parts.

The method of multiplied experiments was successful in raising the quality of phonographic reproduction to a high level but one which still fell far short of perfection. Telephone research work led to the recognition that a phonograph is a wave transmission system, and that the requirements which each part should meet can be determined mathematically. This has tremendously reduced the amount of experimental work required as it is now only necessary to find practical ways of making individual parts whose requirements are fully known. The use of this method has given us a phonograph of a very much higher level of quality with the prospect of practically perfect reproduction in the future. In making the fullest use of the method it has been necessary to develop apparatus for measuring sound output and apparatus for measuring mechanical impedance.

The new phonograph is an illustration of the use in one field of science of methods and knowledge developed in quite a different field. It represents the application to the phonograph of mathematical methods developed primarily for the design of telephone transmission lines and filters. In the early days the theory of electrical wave transmission was commonly explained in terms of analogous mechanical systems, and now reversing this process, telephone transmission theory has been used to design the mechanical wave transmission system of the phonograph. It may not be evident at first glance that mathematical equations worked out for electrical systems may be applied to mechanical systems with merely a redefinition of the constants. If, however, the equations for analogous electrical and mechanical systems are worked out and compared, they are seen to be identical in form and to differ only in their constants. This rests

FIG. 1. MR. HENRY C. HARRISON, THE AUTHOR OF THIS PAPER AND DIRECTLY RESPONSIBLE FOR THE DEVELOPMENT WORK ON THE PHONOGRAPH, EXPLAINS SPECIAL FEATURES OF THE DIAPHRAGM TO MR. JOSEPH P. MAXFIELD, IN WHOSE DEPARTMENT THE WORK WAS CARRIED ON.

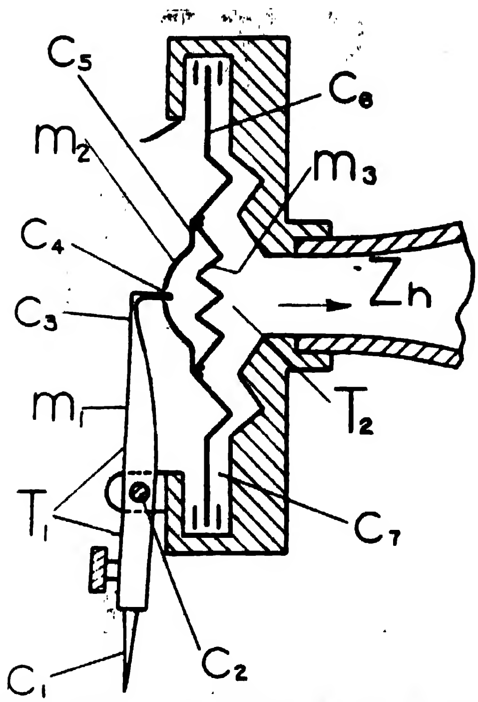


FIG. 2. DIAGRAMMATIC SKETCH OF THE MECHANICAL SYSTEM OF THE PHONOGRAPH.

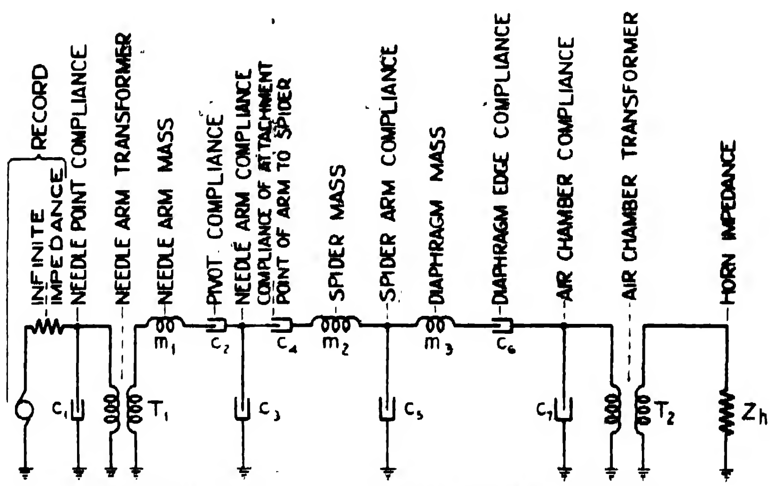


FIG. 3. ELECTRIC EQUIVALENT OF THE SYSTEM SHOWN IN FIG. 2.

on the fact that energy obeys the same laws whether it be in the electrical or mechanical form, and that the characteristic of a system for the transmission of wave energy depends upon three factors: its energy storage elements, its energy dissipation elements and their arrangement. The two common types of storage elements of an electrical system are inductances and capacities, and for mechanical systems the corresponding storage elements are masses and compliances, popularly termed flexibilities. Similarly, the one common type of dissipation element for electrical energy is an electrical resistance and the corresponding feature in the mechanical system is a mechanical resistance. A list of similar correspondence follows:

Mechanical		*Electrical*	
Force = F	(dynes)	Voltage = E	(volts)
Velocity = v	(cm/sec)	Current = i	(amp)
Displacement = s	(cm)	Charge = q	(coulombs)
Impedance = z	{Mechanical ohms dyne secs/cm}	Impedance = Z	(ohms)
Resistance = r	(dyne secs/cm)	Resistance = R	(ohms)
Reactance = x	(dyne secs/cm)	Reactance = X	(ohms)
Mass = m	(gms)	Inductance = L	(Henries)
Compliance = c	(cm/dyne)	Capacity = C	(Farads)

By using this list of corresponding constants a known electrical equation may be readily converted to an analogous mechanical equation.

The new phonograph exclusive of the horn is as a wave transmission system closely analogous to a low pass filter type of electrical system.[2] Figure 2 gives a diagrammatic picture of the physical parts and Figure 3 gives the electric equivalent showing how the parts are related as a wave transmission system. It will be seen that the record acts as an approximately infinite impedance generator and the needle point as a shunt compliance. The needle arm acts as a transformer and also as a series mass and the needle arm tip as a compliance which is in shunt. The spider acts as a series mass and its arms as a shunt compliance. The diaphragm acts as a series mass and its edge as a series compliance. The air chamber acts as a shunt compliance and also as a transformer and the horn acts as a terminating impedance which above its low frequency cut-off is a resistance. The wave energy generated by the groove travels through the needle arm to the spider, to the diaphragm, to the horn and out to the air. In traveling from one end of the needle arm to the other it is decreased in force, that is, the arm acts as a step-down transformer. At the diaphragm the wave energy changes from its form as the vibration of masses and springs to vibrations of the air or sound. In going from the diaphragm to the horn the total pressure of the sound waves is decreased, that is, this is a step-down transformer. Thus it is seen that the wave energy in its travel from the needle point to the mouth of the horn passes through a complex series of variations and transformations and all of these must be accomplished without loss or distortion and that for the whole range of voice and music frequencies. Mathematical studies of telephone lines and filters have shown that a transmission system such as the phonograph will transmit the whole voice and music range of frequencies without distortion if three conditions are met. First, the parts of the system should be arranged to form repeated filter sections; second, the magnitude of these quantities should

[2] A complete explanation of the matter may be found in a paper presented at the Mid-Winter Convention of the A. I. E. E., February 12, 1926.

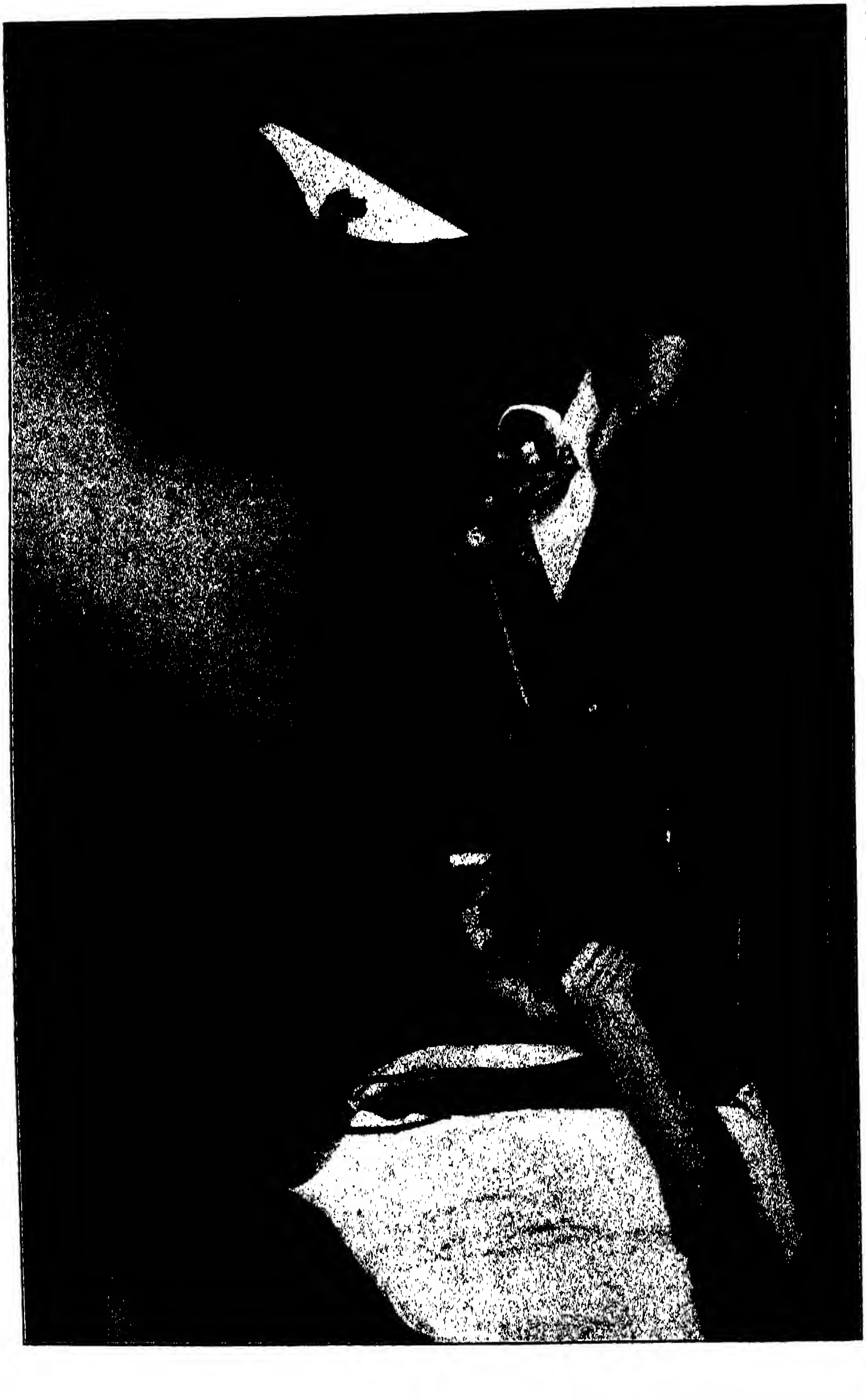


FIG. 4. MR. ALBERT L. THURAS (RIGHT) AND MR. THEODORE OSMER (LEFT) MAKE MEASUREMENTS ON THE PHONOGRAPH WITH A MECHANICAL IMPEDANCE BRIDGE.

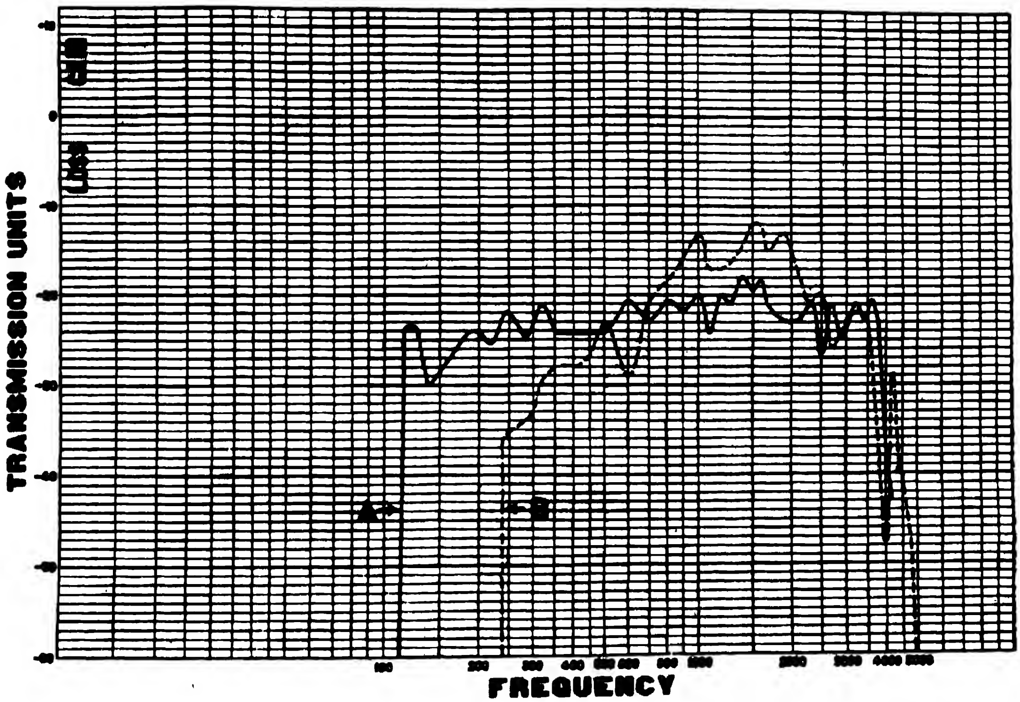


FIG. 5. RESPONSE FREQUENCY CHARACTERISTIC OF TWO PHONOGRAPHS. CURVE A SHOWS THE CHARACTERISTIC OF THE BAND PASS FILTER TYPE DESCRIBED. CURVE B SHOWS THE CHARACTERISTIC OF ONE OF THE BEST PREVIOUS MACHINES.

be such that without transformers the separate sections all have the same cut-off frequencies and characteristic impedances and third, a proper resistance termination should be provided. These conditions were not met by older phonographs, in fact, it is very improbable that they ever could have been discovered or met by the experimental method alone. It was the failure to meet these conditions in the older phonographs that was responsible for their imperfect quality.

For the perfect reproduction of speech and music it is necessary to reproduce the range of frequencies from below 30 to about 10,000 cycles, but a high degree of naturalness is achieved with a range of only 100 cycles to 5,000 cycles. This is approximately the range of the new phonograph but it is anticipated that further development work will extend this somewhat. In figure 5 curves are given showing the range of reproduction both of the new phonograph and of one of the best of the older commercial types. The new type satisfactorily reproduces a little more than 5 octaves whereas the old satisfactorily reproduced only about 2 octaves. In contrast to what is heard on the older phonograph, a person listening to the new phonograph hears the low frequencies as well as the high. Its reproduction of the low frequencies gives naturalness to speech and music, makes it comfortable and carries over the full power of the rhythm. Its high frequencies give clarity and detail. They move the artist's voice from a position down in the throat of the horn right out into the room. They make all the instruments in an orchestra stand out individually, each with its own individual quality of tone.

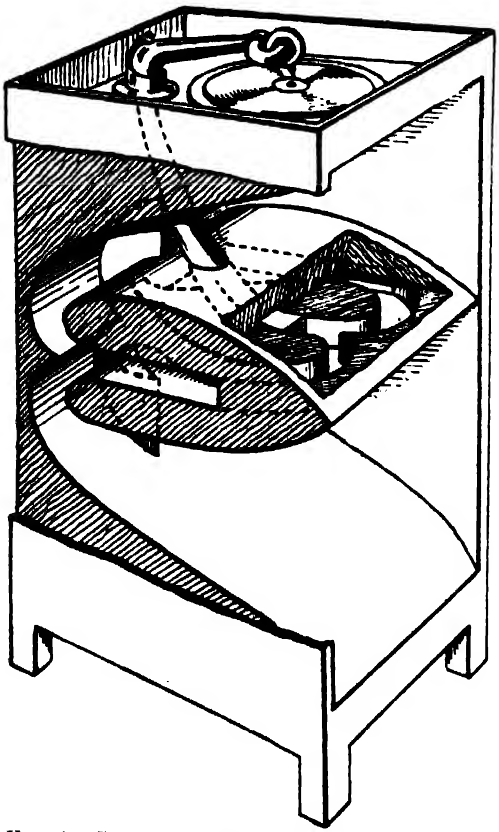


FIG. 6. SECTIONAL VIEW OF THE FOLDED HORN SHOWING THE AIR PASSAGE.

On the new phonograph, not only is a satisfactory range of frequencies reproduced but it is reproduced without partiality, that is, without regions of exaggerated loudness or weakness. We are all familiar with such examples of partiality as the resonance of an empty room or the sound that one hears when one speaks with his head in a rain barrel. These changes in quality are, technically speaking, changes in the distribution of sound intensity with frequency. All speech and music are made up of simple sine frequencies, that is, simple flute-like tones of various pitches and various intensities, the various vowels being distinguished not by the fundamental but solely by the distribution of intensity among the overtones. Because elements of speech have this character, one may speak into a resonator such as a barrel of just the right size and find that although he speaks one vowel a different one is heard. A phonograph with the same peak will make the same change.

In appearance the new phonograph with a sound box, tone arm and horn is not unlike ordinary types as shown in Fig. 6. The sound box, tone arm and the horn are designed as parts of a mechanical transmission system and this has led to several new features. For example, the sound box uses a new type of diaphragm.

In order that the vibratory energy shall pass without reflection loss from diaphragm to air chamber, the diaphragm must be very light—.0017″ duralumin is used. But thin duralumin has a metallic rattle when vibrated. To eliminate the rattle, the diaphragm is corrugated all over with such close spacing between corrugations that the flat portions all have natural periods well above the range of speech frequencies. The central two-thirds is corrugated in concentric circles to stiffen it. Between the stiffened central area and the clamped edge tangential corrugations are used to attain four results. First, rattle is eliminated; second, the annulus is made more flexible; third, large amplitude of vibration without distortion is made possible; fourth, neither the flexibility nor the uniformity is destroyed by a slight dishing of the diaphragm in or out and hence solid clamping can be used even with surfaces that are not perfectly true.

Another special feature of the diaphragm is the method of driving it at a number of points by a spider. The central portion of the diaphragm is made to move as a plunger by driving it at six points on a circle near the boundary of the stiffened area. The six legs which attach to the diaphragm are made flexible in order that the spider and the diaphragm shall not vibrate together, their masses adding, but in sequence. That is,

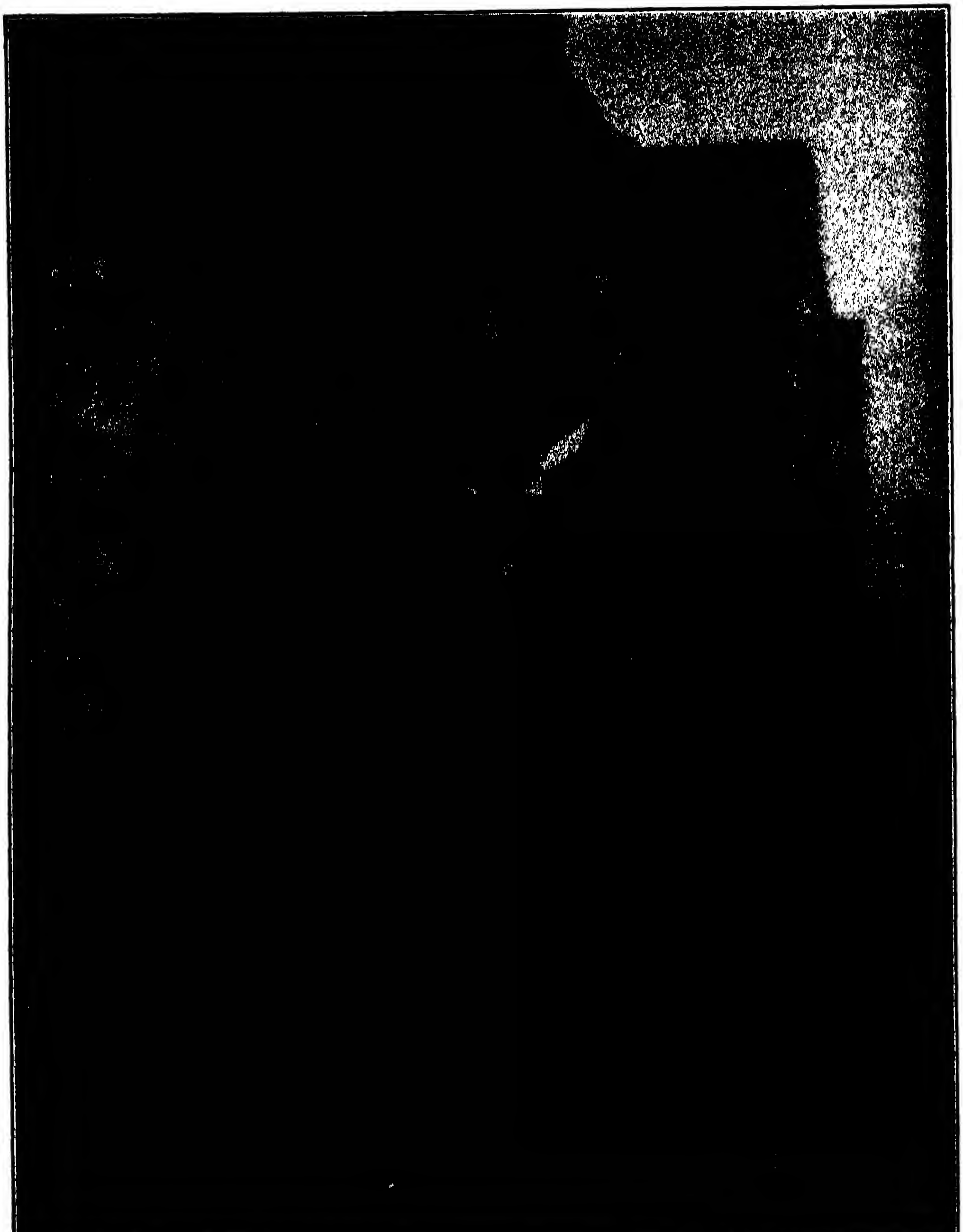
FIG. 7. THE NEW ORTHOPHONIC VICTROLA, WITH MME. GALLI CURCI LISTENING TO THE REPRODUCTION OF HER VOICE.

the spider is another section of the mechanical transmission system.

Another special feature of the sound box is the needle arm bearing. Ordinary knife bearings are not of sufficiently high elasticity as fulcrums and the rotational elasticity as well as the rotational friction is undesirably large. A construction which has been found to meet these requirements is a ball bearing with the steel balls held in position by magnetism.

The other feature which distinguishes the new phonograph is its horn, shown in figure 6. This differs from those ordinarily used in two important respects —it is of logarithmic design, *i.e.*, its area increases by a uniform per cent. for each increment of length and it has a mouth opening adjusted to its rate of taper. The advantage of the logarithmic shape is that for a given volume of horn it gives the greatest effective frequency range of reproduction. The logarithmic shape is continued throughout the whole length of the tone arm, making the tone arm a part of the horn.

With a given rate of taper of horn there is a best mouth opening in order to prevent peaks in the low frequency region of reproduction and this is used. To reproduce frequencies down to 100 cycles with a standard size reproducer diaphragm, a horn about 6 feet long is required. The problem of such a large horn is to a considerable extent that of the size of the cabinet, and a method of folding up the horn has been developed which permits a 6-foot horn to be placed in a standard size phonograph cabinet. It will be noticed that the sound passage is always bent in its thin direction which facilitates sharp turns and compact folding.



WILLIAM BATESON

DIRECTOR OF THE JOHN INNES HORTICULTURAL INSTITUTION NEAR LONDON, DISTINGUISHED FOR HIS RESEARCHES IN GENETICS AND OTHER BIOLOGICAL SUBJECTS. THIS PHOTOGRAPH WAS TAKEN WHEN DR. BATESON CAME TO AMERICA FOUR YEARS AGO AT THE INVITATION OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE TO GIVE AN ADDRESS AT THE TORONTO MEETING. THE ADDRESS ON "EVOLUTIONARY FAITH AND MODERN DOUBTS" ATTRACTED MUCH ATTENTION BECAUSE IT QUESTIONED THE DARWINIAN THEORY AS A SATISFACTORY EXPLANATION OF EVOLUTION AND WAS QUOTED BY MR. BRYAN AND OTHERS AS ADVERSE TO THE DOCTRINE OF EVOLUTION.

THE PROGRESS OF SCIENCE

THE STERLING MEMORIAL LIBRARY OF YALE UNIVERSITY

PLANS for Yale's new monumental Gothic library, designed to house 5,000,000 volumes, and to be erected as a great memorial to the late John W. Sterling, eminent Yale graduate of the Class of 1864, at an estimated cost of $6,000,000, provided by the trustees of the Sterling estate, have been prepared. The Sterling Memorial Library has been designed not only to give immediate facilities for the proper use of Yale's priceless collection of books, accumulated during two centuries and a quarter, but also to meet the university's library needs for the next hundred years.

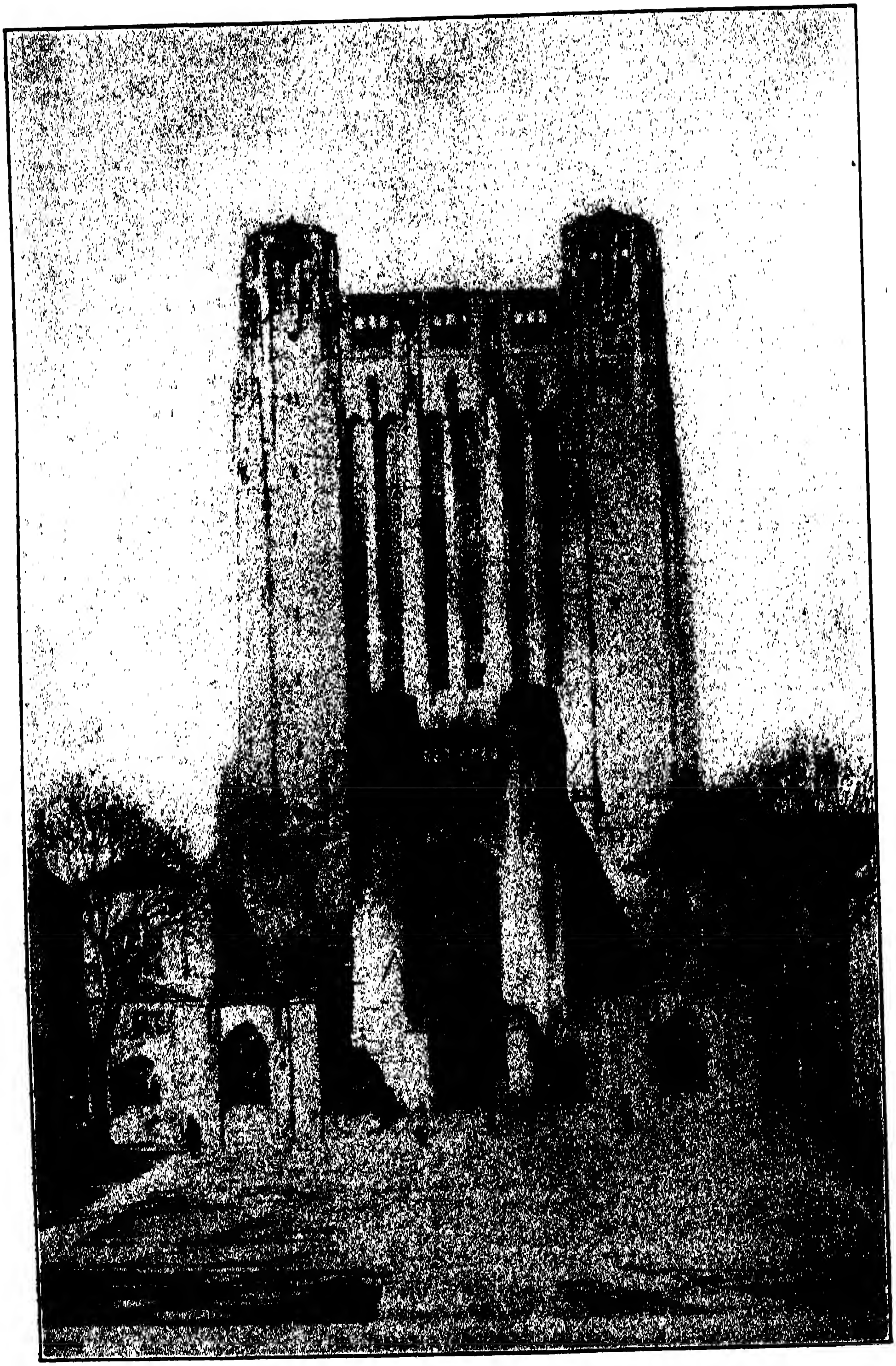
It is expected that the construction of the building will be completed two years from now. It will then probably be the largest and best-planned university library in the world and its special services and conveniences will be unsurpassed. The architect is Mr. James Gamble Rogers, of New York. In outward appearance the new library will harmonize with the Harkness Tower and the Memorial Quadrangle, which are also the work of Mr. Rogers. Andrew Keogh, librarian of Yale University, says that the plans will give the university "a building as efficient as an up-to-date factory and as beautiful as a cathedral." The stipulations given the architect were for good light, flexibility of construction to provide for changing needs, quiet, comfort, quick service for readers, and an inspiring atmosphere.

In the new building 2,000 readers in all may be seated at one time. All the main reading rooms are to be on the street level. When the building is opened there will be available 1,600,000 volumes, besides more than 10,000 periodicals. Accessions to Yale's book collection are now at the rate of 1,000 a week.

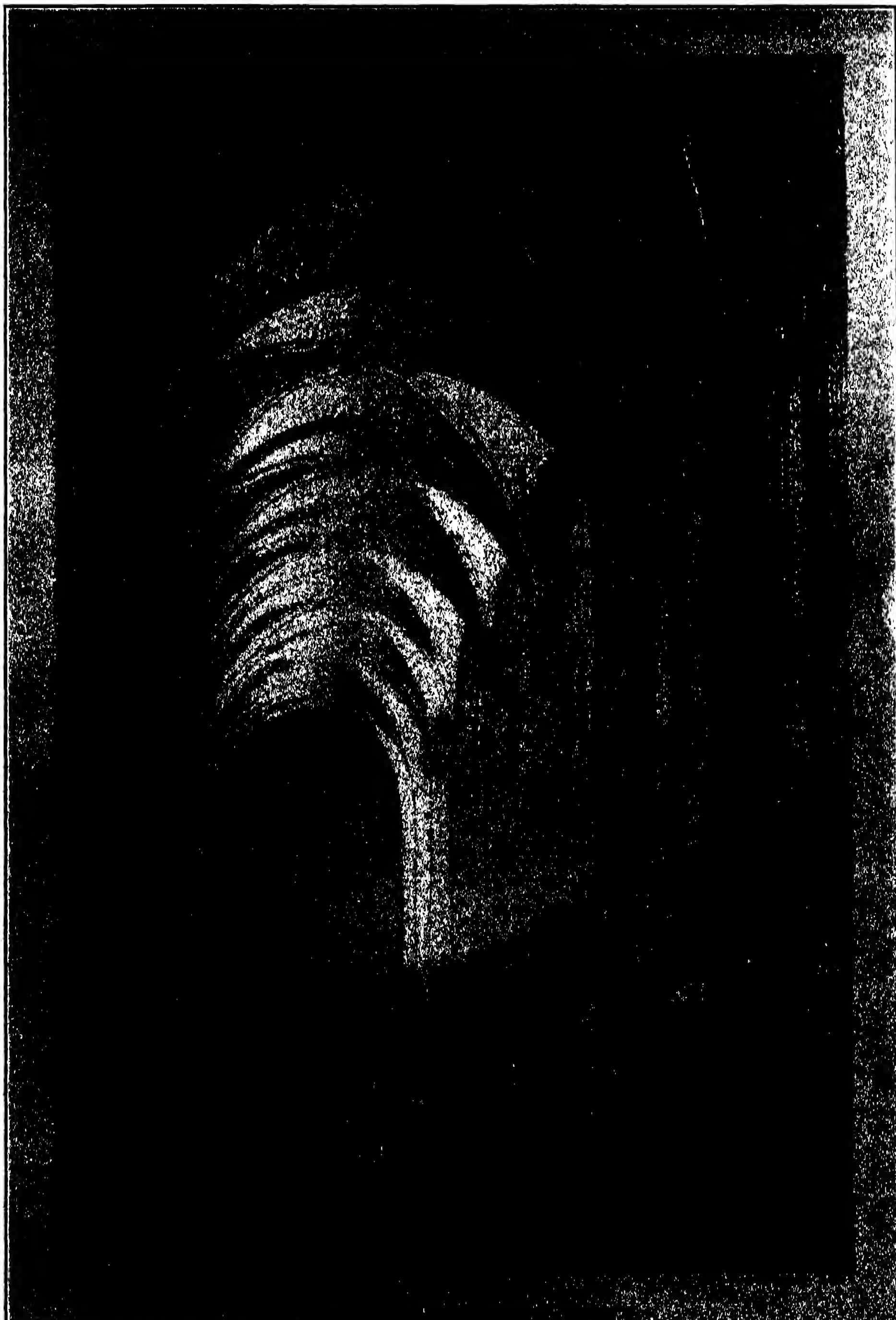
One hundred and ninety-two feet high and eighty-two feet square, the dominating feature of the building will be the "book tower," of warm yellow stone and slightly tapering. This will contain twenty-two floors. No shelf will be higher than seven feet, so that all books will be easy of access, and the aisles will be especially wide. Smaller than the book tower, and in front of it, will be an entrance tower. Within is to be the memorial entrance hall, resembling the nave of a great cathedral. Passing through the memorial hall, the future Yale student will find himself in a court, with trees and a fountain and a cloistered walk at one side.

Nearest the main entrance are two reading rooms for undergraduates, one containing reserved books and the other the Linonian and Brothers collections. In the main reading room 15,000 important reference books will be available to any inquirer, and those from adjoining stacks will be brought in by pneumatic carriers. For the creative scholar there will be fifty studies and seminary rooms, and more than 400 stalls in which books and papers may be kept in privacy for a limited time.

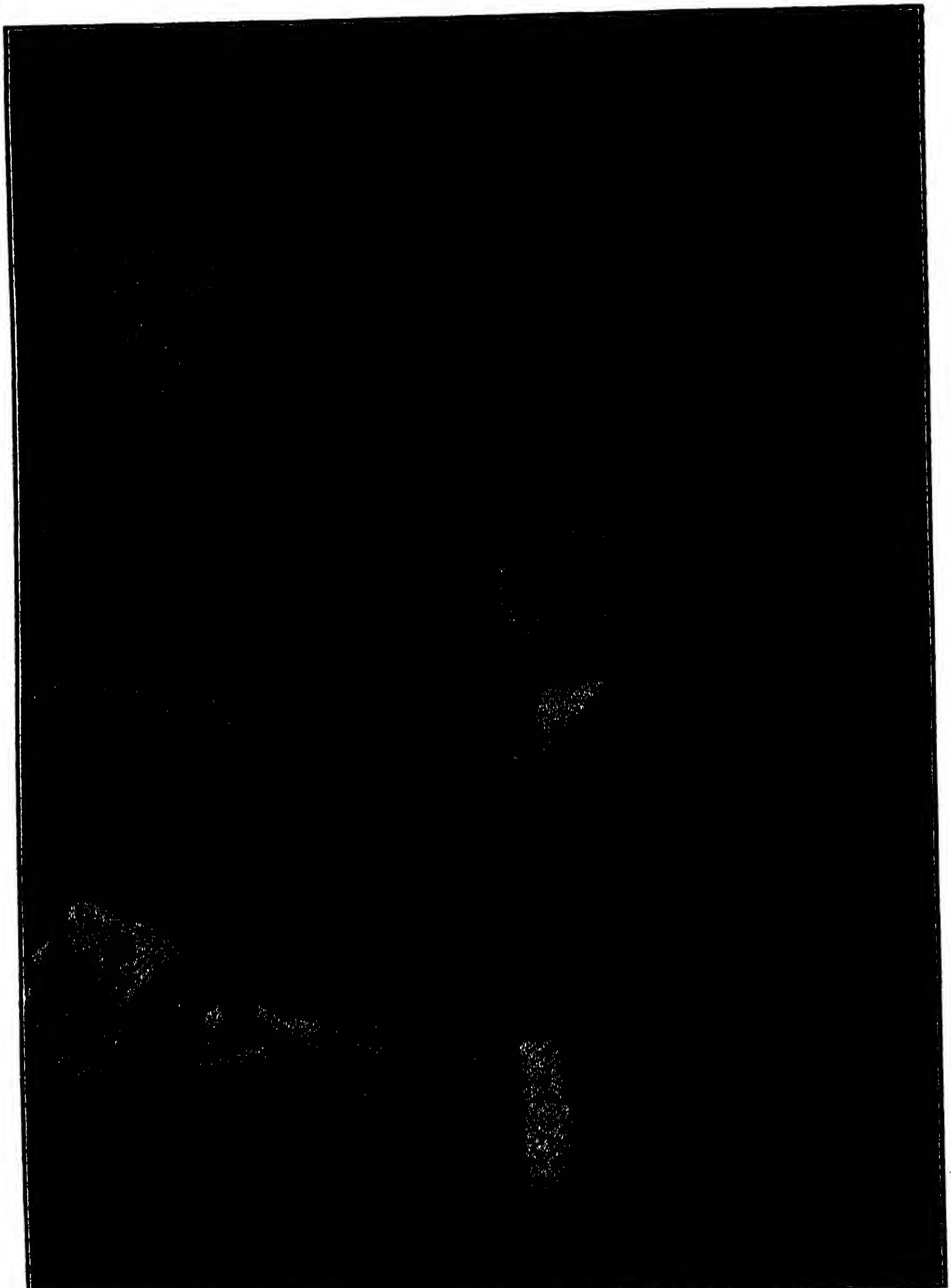
A novel convenience for Yale undergraduates will be the so-called nonresidents' room in the new library. Students living in neighboring towns or in the outskirts of New Haven need a quiet place where they can work between recitations or at other times. This room will seat 300, and there will be cloak room facilities for all. Reference and text



THE STERLING MEMORIAL LIBRARY OF YALE UNIVERSITY



ENTRANCE HALL TO THE STERLING MEMORIAL LIBRARY



EDWARD SYLVESTER MORSE

books will be available and the unique Andrews Loan Library, from which books may be borrowed for a year at a time, is to be here. The librarian, and his staff, in order to be easily accessible to all who may desire expert assistance, will have their offices on the ground floor, adjoining the entrance hall.

EDWARD SYLVESTER MORSE

PROFESSOR MORSE was born in Portland, Maine, and died at Salem, Mass., on December 20, 1925, in his eighty-eighth year. He retained remarkable physical and intellectual vigor. He played tennis until recently and contributed to THE SCIENTIFIC MONTHLY for October, 1925, an important article on shell mounds. An obituary notice by Professor Morse's life-long friend, Dr. W. H. Dall, has appeared in *Science* and from this we quote.

Like most naturalists Morse early showed an interest in natural history, amassing a notable collection of shells at the age of thirteen, and what is less common, he developed unusual artistic ability. He made for Dr. William Stimpson numerous admirable drawings of living mollusks of the Maine coast. In 1859 he became one of Louis Agassiz's special students at the Museum of Comparative Zoology, where he pursued his studies until 1862 when he published his first paper on brachiopods, a subject to which he later made notable contributions. His first paper to attract particular attention was devoted to some minute landshells of Maine, illustrated by his own drawings.

In 1871 he became professor of comparative anatomy and zoology at Bowdoin, remaining until 1874, and also gave a series of lectures at Harvard. In 1876 he was elected a member of the National Academy of Sciences and the following year went to Japan, led chiefly by the desire of studying the Japanese brachiopoda, in which that region is so rich. He received the appointment of professor of zoology at the University of Tokyo, which he filled with great success, returning in 1880 with large collections and signal honors from the Japanese government. During this period his ready pencil was active in taking notes which later formed the basis of his volume on Japanese homes, and other contributions to our knowledge of the Japanese people for whom he always cherished a profound admiration. At this time too his artistic taste recognized the beauty of the common pottery of Japan, and he made of it the remarkable collection which is one of the treasures of the Boston Museum of Fine Arts, of which he was curator.

On his return to Salem he became director of the Museum of the Peabody Academy of Sciences. His work in this institution made the museum the custodian of the most artistically and scientifically arranged minor collection in the United States, if not in the world.

In 1886 Morse was elected president of the American Association for the Advancement of Science, and in the intervals of activity at Salem lectured acceptably in many parts of the United States.

The salient characteristic of Professor Morse, apart from his devotion to science and love of the beautiful in art, was his boyish enthusiasm which captivated all who knew him. The versatility of his interests was unbounded, his love of fun overflowed at every opportunity; to meet him was to find a welcome. The world was brighter for his presence.

DR. SAMUEL C. LIND AND DR. HUBERT WORK

DR. LIND, ON THE RIGHT, ASSOCIATE DIRECTOR OF THE FIXED NITROGEN RESEARCH LABORATORY, IS EXPLAINING TO DR. WORK HIS EXPERIMENTS ON HELIUM. THE NICHOLS MEDAL IN CHEMISTRY FOR 1925 HAS BEEN AWARDED BY THE NEW YORK SECTION OF THE AMERICAN CHEMICAL SOCIETY TO DR. LIND FOR HIS WORK ON THE CHEMICAL ACTIVATION OF ALPHA PARTICLES.

NITROGEN FROM THE AIR

THE United States Fixed Nitrogen Research Laboratory, of which Dr. F. G. Cottrell is the director and Dr. C. S. Lind the associate director, is actively engaged in studies of methods of obtaining nitrogen from the air, which can utilize the vast energy of Muscle Shoals, which is still under the control of the United States government. An article by Dr. Cottrell in THE SCIENTIFIC MONTHLY for September, 1925, describes these methods. A recent bulletin of *Science Service* states that American crops and factories use nearly $75,000,000 worth of nitrogen in one form or another each year, and over $50,000,000 of this comes from abroad, chiefly from Chile. Other kinds come as fertilizer from factory wastes or as ammonia in liquors from coal distillation in the making of gas coke. The rest is made synthetically from the nitrogen in the air by chemical means.

In 1925 the world used 857,000 tons of the element nitrogen, exclusive of that occurring in animal products or foods. Of this amount 44 per cent. comprised the nitrogen in the output of Chile saltpeter, and 56 per cent. was fixed nitrogen.

A monopoly of nitrate producers controls practically the entire output of the Chilean fields. The government of Chile is a party to the monopoly and puts a tax of $12.34 on every ton of nitrate that leaves the country. At present, the price of the nitrate, artificially boosted by the tax, sets the standard for all synthetic nitrates and fertilizers.

It is believed that when the methods for getting nitrogen from the air are further improved and more commonly used, synthetic nitrogen products will turn the tables on the Chilean fields. Recently discovered means of getting nitrogen from the air where it exists in unlimited quantities and in an elusive form, have become of vital importance in peace and war. By these means Germany freed herself from Chile before the war, and the United States might do the same.

As a result of nitrogen fixation it is estimated that 56 per cent. of the world's supply of inorganic nitrogen came out of the air in 1925. Before the war only 10 per cent. was got in that way. The plentiful supply of nitrogen which is in the air and there for the taking, may make it possible for agriculture of the future to meet the demands of the fast-growing population of the world, which is disturbing the sleep of many an earnest economist. There is almost unlimited room for improvement in agriculture. The Department of Agriculture points out that in 1925, out of the forty odd millions of acres planted in cotton, only about 36 per cent. are fertilized.

"What is done with the nitrogen problem in the next ten years will go far to determine American standards of living," according to a statement of Dr. Harry A. Curtis, former chief of the nitrate division of the U. S. Department of Commerce. "Unless relatively cheap fixed nitrogen can be supplied to agriculture each acre will produce smaller crops while our population will continue to get larger."

Although the processes for getting nitrogen from the air are less than twenty years old they already give the world each year an amount greater than that shipped out of the Chilean fields. There are many possible ways of hooking up the obdurate atmospheric nitrogen with materials on earth, but only three of these ways are actually used.

The simplest of these is the electric arc process. Nitrogen is induced to combine with oxygen by the powerful stimulant of electricity. The nitric oxide formed is passed through huge absorption towers where it reacts with water and more oxygen to form dilute nitric acid. The process has been success-

ful in Norway, but the exceedingly high electric power requirement has prevented its use in most other countries.

In the cyanamide process, which was first used in Italy, nitrogen is trapped as it passes over finely powdered calcium carbide heated to about 1,000 degrees. It becomes chemically fixed into solid calcium cyanamide which can be easily changed to ammonia gas or nitric acid. The raw materials needed for making the calcium carbide are coal and limestone, and the energy required is only about one fourth that needed for the arc process. It was found that calcium cyanamide could be put directly into the soil as a fertilizer. This stimulated production, and in 1913 there were already nine producing countries making 172,000 tons of the substance. The production is about four times as great to-day.

The synthetic ammonia process, the newest of the three methods of nitrogen fixation, was not known outside of Germany when the world war began. To-day, however, there are many processes based on the same principle. The pioneer Haber process was worked out mostly by Fritz Haber in Germany between 1905 and 1908. The principle involved has been called the most far-reaching accomplishment of chemical engineering. A properly proportioned mixture of nitrogen and hydrogen gas is passed over a catalyst, a substance that by some seemingly magic influence can make two unwilling elements react chemically toward one another. The combination forms ammonia. Heat is produced, and not absorbed, during this reaction and the more the temperature is kept down and the pressure up the more ammonia is evolved.

A CHILD'S ANATOMY

From *Punch*

Child (to doctor who is making long and careful examination of her spine).—"IF YOU'RE TRYING TO FIND MY TUMMY IT'S ON THE OTHER SIDE."

THE SCIENTIFIC MONTHLY

APRIL 1926

RESEARCH AND INDUSTRY

COOPERATION BETWEEN INDUSTRY AND UNIVERSITY[1]

By GEORGE D. McLAUGHLIN

DIRECTOR, RESEARCH LABORATORY OF THE TANNERS' COUNCIL OF AMERICA, UNIVERSITY OF CINCINNATI

ANY one who has even superficially recognized the economic conditions of the world in which we live or who has attempted to analyze these conditions is impressed with the large rôle played by industrialism.

On the one hand is to be found that group termed "industrialists," whose work in the final analysis consists largely in the creation of financial profit from their investments. The other extreme, so to speak, is represented by scholars, housed in our universities, whose avowed purpose is the creation of a better world and the meeting and solving of the intellectual and practical problems confronting the modern age. Rarely has an adequate understanding between the two groups been reached. The average industrialist (I say average, because there are notable exceptions) feels the scholar to be quite out of touch with the "practical" problems of the day. He may vaguely admit a possible need for the thinker or the theorist, but to him the man of "action" is important. The scholar (and this includes the research scientist) is often moved with a feeling bordering upon contempt for the industrialist. He feels that aims, born and executed from a purely monetary standpoint, are, when viewed in the light of intellectual progress, futile and unworthy of serious consideration. As a result, we hear complaining voices grown eloquent in decrying the commercialization of our universities and the alleged lack of appreciation of knowledge for its own sake.

It is not my purpose here to weigh the special arguments of either group, since in my opinion the extremists on either side present conclusions based upon superficial grounds and so contribute little towards progress. I am interested in showing that, whether we like it or not, the problem of the relation between industry and university is with us and cries for answer. There is at least one answer to this question, which I will attempt to describe.

The life of every university depends upon its receiving, each year, the funds necessary for its conduct. These funds, whether received by the university as tuitions, endowments or taxes, represent a portion of the wealth produced over and above the actual living costs of the population of the community supporting the institution. In a previous age these moneys came largely from the fruit of the soil; to-day they result mainly from

[1] Paper presented before Section K—American Association for the Advancement of Science—Kansas City, Missouri, December 29, 1925.

the dividends paid directly or indirectly by industry. When industry ceases to pay dividends the university must close.

The life, the growth of industry depends directly upon the quality of the university scientist. Few industrialists understand this; captains of industry and finance, proud in the realization of their power and remembering the power plants, the fleets of ships or the compound locomotives which move at their command, vainly imagine that all this is their creation; the fruit of their dynamic, restless toil. Their only accomplishment is the organization and marshalling of certain forces. The forces which make possible all these activities were discovered, in almost every instance, by a scholar whose knowledge of either high finance or "scientific management" hardly equalled that of an office boy. Having made the observation he passed it on and turned to other problems. Instances of this, in almost every industrial field, could be endlessly related. Not long ago I heard an industrial group describe, in terms of admiration, the very large sum paid a comparatively young man for a radio business which he had "built up." I asked in what proportion the credit should be divided between this man and Clerk-Maxwell. They knew of no one in the radio business named Clerk-Maxwell. An industrial captain recently expressed his profound disapproval of the graduate school of a well-known university, maintaining that its cloistered walls unfitted students for grasping the important, practical problems of business. He was evidently ignorant of the fact that his own industry was born in such rooms; nor did he realize that the next and logical development of this industry is now awaiting the results of the work —not of his efficiency experts or business prognosticators—but of research scientists, whose very names he probably does not know.

I do not fear the commercialization of our universities. The strength and value of such institutions depends solely upon the character and ability of the men composing them. Strong men will not be commercialized. Nor need we be apprehensive lest the pursuit of knowledge for its own sake shall perish, or the love of scholarly pursuits, if we will only remind ourselves that human nature changes slowly, if at all. Scholars will continue in the future, as in the past, to represent a quite small percentage of the student rank and file, but they will continue in the future to appear and to do their work because they love it.

If scholars and industrialists will realize that their diverging tastes are equally legitimate (since even scholars must be fed, clothed and transported), that each is entitled to pursue the work at hand, and that, after all, they have something in common, both will be benefited. This common point of contact has, during the past four years, been partially achieved by the Tanners' Council of America and the University of Cincinnati.

The Tanners' Council is composed of the leather manufacturers of the United States. Tanning is a basic industry, since leather is needed for shoes, harness, belting, upholstery and many other uses. It is one of the largest American industries from the standpoint of capital investment. The tanning of leather was one of the first steps of civilized man. Throughout many ages and into the present day tanning was an empirical practice, the "secrets" of which were handed down from father to son. This was the result of an abundant supply of cheap raw material and mild competition. Under the stimulus of diminishing supplies of domestic raw materials and ever-increasing competition, a new viewpoint was born. Progressive members of the industry realized that if they were to maintain or advance their position,

the scientific laws underlying the materials and processes of their industry must be written.

The processes of tanning involve the conversion of the animal tissue skin into the useful, imputrescible article called leather, by means of tanning agents, both organic and inorganic. The science of tanning involves nearly every important branch of chemistry, just as in the problems of the modern medical investigator of other animal tissues; it involves also the action of bacteria and the histological picturing of structural changes. Such far-flung and fundamental studies called for a variety of scientific talent, for physical equipment and for time.

The council wisely turned to a university. A gentlemen's agreement with the University of Cincinnati was reached which has subsequently become the basis of a formal contract. The agreement is brief and simple and provides that: (1) no research work shall be undertaken which is not of a strictly fundamental character, which means, of course, that no "hack" work or special problems of particular contributing corporations will be considered; (2) the council will furnish the funds needed for the prosecution of the work; and (3) the results of all research will be freely published in reputable scientific journals.

From the viewpoint of the average industrialist the contract is unbusinesslike; from the standpoints of the really progressive manufacturer and the university it is the only adequate method of meeting the problem, of ensuring work of a fundamental quality and of attracting to it men of university caliber.

The agreement has "worked" in practice. During the early stages of the research there were, as would be expected, expressions of discontent from the less progressive, unimaginative members whose understanding of fundamental conceptions was necessarily vague and who expected the tree to grow to maturity and yield a golden crop within a month after planting. Another well-meaning group felt the urge of offering suggestions of "problems" demanding immediate attention, without, of course, any conception of whether their suggestions had a scientific basis. When such misdirected, though well-intentioned, efforts possess sufficient pressure, the scientist (whom the industrial group looks to for "results") often loses heart, his enthusiasm is dampened and, realizing the futility of the situation, he simply resigns. Or, if he lacks sturdiness, he is overawed by the powers before him and begins a necessarily fatal compromise; he seeks to pacify one group by investigating some probably wholly unessential problem they suggest. Scarcely is this done when another group, or a particular corporation, not to be outdone, advances with a suggestion; the precedent has been established and he must meet their demand. In a comparatively short period the scientist's time and energy are divided between routine analytical or testing work and a feverish effort to placate the ever-growing disappointment of the industrial group which had been led to expect large increases in their dividends. Thus the undertaking which started with the martial strains of a brass band ends with the weak notes of a harmonica. The net result is that a substantial sum of money has been wasted and nothing gained but disillusionment.

The foregoing conditions were realized by a committee of progressive members of the council, who took the steps necessary to safeguard the research laboratory. This committee functions as a buffer between the laboratory and the industry. Expressions of complaint or suggestions of problems are sent to them and are given consideration and reply. If the matter is of importance it is sub-

mitted to the laboratory, for the director's consideration. Thus, for four years, the laboratory at the University of Cincinnati has been enabled to concentrate upon essentials. It has formulated certain laws. For example: the curing of animal skin following slaughter is of great importance; the skin is cured so that it may be transported from abattoir to tannery without bacterial decomposition. The laws underlying this process were established, and to-day, instead of a heterogeneous mass of unrelated observations and data, there exist simple, clear-cut laws which govern the curing of any skin, be it rabbit, ox or elephant, and whether it is slaughtered in Chicago, Hong-Kong or Capetown. Again, a very important tannery process is termed "soaking," by which the skin is prepared for the unhairing treatment. The laws governing this process have been evolved. They have been applied by a dozen large corporations to meet their special conditions. Each of these corporations has been enabled to secure more and better leather from a unit of raw material and at no additional manufacturing cost. In other words, the work has produced wealth far in excess of its cost.

With the rapid but healthy expansion of the research work came the need of increased laboratory facilities. It was now no longer a question of whether the work would pay; this had been proved. The council consequently built and equipped upon the university campus a laboratory building which they gave to the university. This building is a handsome three-story brick and concrete structure, containing private research laboratories for the heads of the various departments of the work, general laboratories and private laboratories for post-graduate students, lecture-room and museum. One entire floor is devoted to chemical studies, another to bacteriology and a third to histology.

I have thus outlined one answer to the problem of the relation of university and industry. Wealth has been produced for industry and the university has been supplied the funds and facilities for the prosecution of scientific research. Each group has gained, neither has lost.

It may be correctly argued that the motive guiding the expenditures of the council lies mainly in the hope of greater profits rather than in the furtherance of knowledge for its own sake. Equally true, however, is the fact that these increased profits are the surest means of interesting industry in the general activities and aims of a university. If industry shall ultimately assume its proper share in supporting general education and research—whether in the arts, the sciences or the humanities—it will be because the university has shown itself to be the ultimate source of increased dividends.

THE FRONTIERS OF INDUSTRY[1]

By EARL P. STEVENSON

RESEARCH DIRECTOR OF ARTHUR D. LITTLE, INC., CAMBRIDGE, MASSACHUSETTS

We are indebted to many scholars of antiquity for bits of wisdom which, in their modern acceptance, can claim the quality of truth. There is the story of the emperor who called a conclave of scholars for the purpose of reducing the wisdom of the ages to a four-word summary, and on this present occasion the four-word report of that ancient convention is worthy of attention: "This too will change."

So long as industry deals with matter in the aggregate, considers the atom as an abstraction and the electron remains on the border-line of metaphysics, the opportunity for effecting fundamental changes in industrial processes should not be qualified. The field for useful inventions in the arts is kept fertile by new scientific discoveries, and never more so than to-day, with the quickening rewards of continued attack on the very substance of matter. The atom, as Dr. W. A. Whitney recently stated, presents a challenge for further study. "Thus far the more we have sought to understand them, the more we have gained in appreciation of an unexplored, unlimited territory of interest and service."

What new opportunities for achievement lie beyond the present frontiers of our scientific knowledge should not, however, be our only concern. The frontiers of science are further flung than those of industry; we must accept this fact and quicken our pace lest we pay further and greater tribute to those nations whose people have come to realize the great industrial opportunity that awaits a fuller appreciation of data already before us. We have passed through a period of epoch-making discoveries; if we are to more completely realize upon their potentialities our recourse is intensive research, wisely directed, adequately financed and sustained in the face of obstacles. To better cope with this situation, more energy should be concentrated on the frontiers of our industries.

Organized research does not depend upon individual genius; it is a group activity, as distinct a business activity as selling merchandise; it is as capable of organization and direction; so-called business methods are equally productive in its administration. Supermen are not required. While the individual may indulge the vagaries of his imagination, the realization is unavoidable that the immediate opportunity to-day is of a different kind than when Charles Watt in 1851 covered within the brief disclosure of a single patent specification the principles and practice of our present-day electrochemical industry. There are few such manuscripts as Watts' patent, British No. 13,755, for explicitness and inclusiveness. Consider the four brief claims:

Firstly, the mode of decomposition by the agency of electricity saline or other substances in solution by means of a vessel divided into two or more compartments separated from each other by partitions of porous material.

Secondly, the mode of preparing or obtaining the metals of the alkalies and alkaline earths by the action of electricity and heat.

Thirdly, the mode or modes of converting chlorides of potassium and sodium and the metallic base of the alkaline earths into hypochlorides, and chlorates of the alkalies and alkaline earths.

[1] Paper presented before Section K—American Association for the Advancement of Science—Kansas City, Missouri, December 29, 1925.

And fourthly, the separation of metals from each other by the agency of electricity and by means of vessels divided into compartments separated from each other by porous partitions and at the same time freeing such metals from other impurities.

Few are endowed with such genius as his for revealing new planets in our industrial system, but as the demand today is for intensive development, the tasks are of all orders, and many can qualify.

Possibly we are too much concerned with the evolution of industries, in effecting minor improvements in old processes, and under-emphasize in our research programs the opportunities for revolutionizing our practice of these processes. Living in the midst of abundant natural resources, we are not as responsive and sensitive to the significance of certain scientific observations in affording the suggestion of a new process as certain less endowed nations. We have so far been content, for example, in the exploitation of our petroleum reserves, with their utilization as fuel and lubricants; while the possibility of producing therefrom edible fats and oils, or developing a wide range of by-products, which affords a promise on a par with the coal-tar industry of twenty-five years ago, has not actively interested us. But this situation will change, is changing, in fact. We are coming to appreciate more the need for intensive research.

At this stage of our industrial development, a major advance in any field comprehends many collateral lines of work, often in superficially unrelated fields. Consider the instance of the new lacquer finishes which, within the past two years, have awakened the varnish industry from the feeling of security born of years of prosperity in the practice of processes inherited from the third century. To provide the automobile manufacturer with this new finish, the chemist can now obtain the necessary nitric acid through the fixation of atmospheric nitrogen; the cotton gin supplies the cellulose from the previously wasted linters; from coal and minerals come the colors; and, lastly, the essential ester solvents can be derived from petroleum. To this end the chemist has successfully exercised his art upon the entire known cross-section of the earth. This is but one example of the productiveness of systematic research.

Research, which gave to Germany her prewar monopoly of dyestuffs and to which she looks for her economic rehabilitation, is too often viewed apart as an ultra, rather than an intra, activity. The needs of research for financial support deserve recognition more on a par with the other agencies and divisions which comprise the machinery of production and distribution. In the face of millions for advertising products by slogans in the absence of distinctiveness in quality or utility which research alone could provide, research expenses are too frequently listed by the accountant among miscellaneous and sundries.

We have already paid the price of our failure to recognize in full the earning power of research. But a very few years ago, the American rights under the viscose patent for artificial silk went begging in this country for fifty thousand dollars, and last year witnessed the production in this country of thirty-six million pounds, valued at eighty-one million dollars, by a foreign-owned corporation that had the vision and faith necessary to finance this project through its development stages.

However parsimonious we may be in supporting fundamental industrial research, millions flow freely into the design of new and improved machinery for the operation of old processes. A million dollar expenditure on a new machine for forming sheet glass is considered quite in order, but glass is still brittle and easily shattered. A decrease in the insurance rates on plate glass is considered highly improbable, because the name glass connotes liability, and we continue

to pave our driveways with broken milk bottles because our milkman has not been sold to the idea that research could give him a tougher and less easily broken bottle.

While I could not justify the expense of a research directed toward a reversion in our preconceived ideas of glass, as there are more likely subjects in closer range of our present knowledge, a silk purse has, nevertheless, been made from a sow's ear. We may not always be dependent upon the fusible silicates for a transparent material. In fact, even now we hear from abroad of an organic glass, possessing remarkable properties, among which is the ready transmission of ultraviolet light. Its discovery was not an accident, but the culmination of years of work lacking in such tangible evidence of progress as might justify its continued support.

Examples without end could be cited where money has been liberally spent on machine design. A hundred thousand dollars to make a paper lard bucket in an automatic machine for your butcher's edification shows laudable enterprise. The idea can be sold and kept sold. The savings over one machine operation in contrast with three formerly used is tangible, and as the design progresses there is tangible evidence of progress. First comes a series of blue prints and pencil sketches—week by week gears are added and subtracted and new mechanical movements introduced—then comes in all probability a small wooden model that can be cranked by hand—later we have the assembly of a full-size model that doesn't perform, but never mind, the gears clank and it looks interesting. In the meantime, our more imaginative competitor has conceived an entirely new type of lard and ice-cream pail—a paper can, so our one hundred thousand dollar machine is idle most of the time.

A way should be found to place research, which aims to better utilize energy and materials for our daily use and is more concerned with primary processes, on a more even competitive basis for financial support with those projects which promise a more immediate return by effecting labor savings and larger scale operations in standard processes. This cause is undoubtedly advanced by such publicity as has been given the much-heralded new German process for making methanol from blue water gas. As the wood distillation industry in this country faces the possibility of losing its investment, which has been estimated at one hundred million dollars, it at last sees the handwriting on the wall. A few years ago, it is reported, an expenditure of eight thousand dollars a year for research was vetoed by the directors of one of these concerns in this country. The action, from one angle, was a proper one. The sum was entirely inadequate; but a request for fifty thousand dollars a year would never have had a hearing. The scheme would have been branded visionary at the directors' meeting, and the perusal of the current balance sheet would have continued, with much discussion of accounts receivable, for the auditor is a member in full and regular standing at these directors' meetings.

For reasons which I shall not attempt to further expound, the idea which is here entertained has found a more fertile field abroad. Our processes are too generally imported. The list is a long one, including the byproduct coking of coal, which in 1924 recovered values to the amount of one hundred and four million dollars formerly wasted by our beehive ovens; the flotation of ores not amenable to economic treatment by our purely mechanical processes; the fixation of atmospheric nitrogen; the viscose process for artificial silk; the basic syntheses for dye manufacture; both the Bessemer and the open hearth processes of the iron and steel industry; the sulfate process for pulping wood; and too many more.

Few of these fundamental processes of industries were without a substantial

prior art in advance of their commercialization. For example, the reaction between hydrogen and carbon monoxide which is employed in the new process for the synthesis of methyl alcohol was first noted by Solvay and Slense in 1898. Here was a recorded fact, but its commercial significance was not immediately apparent, and required years of research for its development. The Badische Company report 1914 as the starting date of its development of this process, which did not culminate in the installation of a commercial unit until 1924.

While numerous examples paralleling the instance of synthetic methyl alcohol could be cited, they would only serve to emphasize the apparent fact of the indebtedness of present-day industrial research to the past. Our concern should be rather to scan these volumes of scientific observations for suggestions of significance to the solution of current problems. The records of organic chemistry are rich in these suggestions, but I will limit myself to the mention of only two.

The gas companies of this country, with their aggregated investment in excess of a billion and a half, consume annually in the neighborhood of fifty million gallons of gas oil for the enrichment of blue water gas. This is a major cost amounting on an average to fifteen cents per millimeter with gas oil at five cents a gallon; moreover, the industry is concerned over its supply for the future. This problem of carburetting blue water gas is of recognized national importance. Among the interesting possibilities is the long recorded reaction between carbon monoxide and hydrogen, both constituents of blue water gas, to produce methane, an ideal enrichment gas.

Then we should be interested in the production of synthetic rubber as consumers of more than six hundred million pounds, or 70 per cent. of the world's production, all imported and exacting an annual tribute close to a half billion dollars. Synthetic rubber is more than a dream, for it has been not only realized in the laboratory, but during the war was produced in large quantities in Germany. It can be made from a certain class of hydrocarbons, known as the diolefines, through a process called polymerization. Now these diolefines are not in the radium class for scarcity. In fact, they are produced in large quantities in every petroleum refinery in this country. They are present in crude cracked naphtha, where they are unwelcome and a source of trouble to the refiner who must dispose of them, and his method is by destroying them. They are reported to form gums and generally stick up the valves of your automobile. In order to remove these bodies, the petroleum industry annually suffers a loss close to ninety million gallons of motor fuel valued at nine million dollars, and incidentally destroys diolefines equivalent to a substantial proportion of our national requirement for rubber.

Here are two typical research problems such as comprise the frontiers of our industries. Instead of a guerilla attack, involving casual work here, duplication there, and general chaos, the great opportunity of organized research, ably directed, sufficiently financed and sustained in prosecution, is evident. Such an enterprise requires imagination, courage and faith in its sponsors. It is a most attractive speculation.

Organized industrial research is a speculation which is of growing appeal to those who are endowed with the vision to comprehend its possibilities and the means to act. The creation of new industries through a research accomplishment is one phase of this appeal.

Confronting new discoveries and advances in every branch of science, the task and obligation of the worker in the field of industrial research is to make these more immediately available for service. Given the necessary financial support, he can speed up and more energy can be concentrated on our industrial frontiers.

Del Mar spoke to the point when he said, "Industrial research is accelerated experience."

RESEARCH, THE PRIME MOVER OF INDUSTRY[1]

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THERE is a time-worn illustration which strikes harder now than when first uttered, because the faith of the man of science has been so overwhelmingly justified. A member of the government to whom Michael Faraday was showing a new experiment in electricity said slightingly, "Very curious, but of what use is it?" "By and by, my lord," replied Faraday, "you may tax it." This prophecy was made nearly a hundred years ago.

In 1925 one of the largest manufacturing concerns in the electrical industry paid an income tax of seven and a quarter million dollars. What factors are responsible for this "time lag," in this instance, one hundred years from the discovery in pure science research to mass production in industry? How are the milestones in progress marked?

They are marked definitely. The successive stages in the development may be designated thus: First, discovery in pure science research; second, applied science; third, invention; fourth, industrial research; fifth, industrial application; sixth, standardization, and seventh, mass production. This is the "cycle of research." It is not measured in volume of production or dollar dividends but in terms of time. The speeding up of the period of the cycle—the reduction to a minimum of the "time lag" from the discovery of the principle to mass production is the criterion of the effectiveness of scientific research as an industrial aid.

Let us trace the development of the electrical industry and determine to what extent it conforms to the pattern of the "research cycle." The "time lag" in each successive stage is emphasized in this chronological outline.

THE ELECTRICAL INDUSTRY

The first stage in the cycle is represented by the discovery of current electricity by Volta in 1779. Working in "applied science," Sturgeon utilized this observation and constructed the first electromagnets in 1825.

Entering the period of "invention," Faraday, based on his investigations in pure science, constructed, in 1831, the first dynamo, which later was destined to "electrify" the world.

The period of "industrial research" is associated with the theoretical work of the physicists Gauss, Weber, Rowland and Hopkinson.

"Engineering development" is linked with the name of Siemens, and the products of the combined labors, theoretical and practical, with the shunt-wound, the gramme and drum armatures, as well as the multi-polar machines, while it remained for Edison to make the "industrial application" by establishing the first central station in 1882 at Pearl Street, New York City.

With the dawn of the era of industrial research as an accepted industrial tool, in 1890 a new generation of engineers, well versed in physics and mathe-

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matics, who mastered the use of alternating current, and to whom belongs the credit for the rapid development of transformers, synchronous and induction motors, and the huge alternators of the present day. The first alternating current line operated at 2,000 volts. Increases in transmission voltage have gone up at the rate of about 9,000 volts a year. About 1900, 44,000 volt lines were in service; in 1912, 150,000; and at present 220,000 volt lines are in service. Every step of the way has been paved by research.

In forty-three years the electrical industry has grown from a single plant to one having a book value of twenty-five billion dollars and a generating capacity of 20,000,000 H.P.

The electrical industry is representative of those comparatively young industries which have taken full advantage of research. Three of the largest concerns in this industry—the General Electric, the Westinghouse Electric and Manufacturing and the American Telephone and Telegraph Companies are together spending about one fifth of the total amount appropriated for industrial research in the United States.

It may seem paradoxical, but is nevertheless true that the older industries have been the last to recognize the importance and value of research work.

To bring this out, in sharp relief, let us trace in chronological outline the development of one of the oldest industries, the textile industry.

The Textile Industry

While the spinning and weaving of textile fabrics is one of the oldest arts known to man, the tools used and methods generally followed only one hundred and fifty to two hundred years ago had changed little, if any, since the days of King Tut. Until 1730 all yarn was spun by hand from slivers or rovings. In 1738 Paul patented a new method of spinning with the aid of rollers. Davenpart, in 1763, took out the first patent granted in the United States for his spinning and carding machines. During the years 1773–1775 Arkwright developed the automatic carding machine and also introduced the factory system into the textile industry. In 1792, the year of Whitney's invention, this country exported 189,316 pounds. In 1812, 237 patents were granted American inventors. A year later, the first mill in the world, in which the whole process of cotton manufacturing from spinning to weaving, was carried on by power. In 1816 Ira Draper patented his self-acting loom temples and in 1823 Arnold invented the compound gear. In 1828 J. Thorpe introduced Crompton's "ring frame," and Kay simplified the work on heavy fabrics by making a shuttle with a handle. Kay's son, Robert, produced the "drop box" by which it became possible to work many different kinds of cross threads into the same fabric. In 1837 William Crompton took out his first patent for a loom to weave figured patterns. About 1845 Arkwright established the factory system in England, while Slater did so in the United States. Lucius Knowles, in 1873, secured protection for the idea which is regarded as the basis of the present-day Knowles loom. The invention of the fancy-dress-goods loom was completed by George F. Hutchins in 1883. In 1895 various mills throughout the country adopted the Northrop loom, which revolutionized weaving as completely as the power loom.

Thus far the development of this industry might be classified an art rather than an industry, as judged by modern standards. But finally it has succumbed to the research idea introduced within the last twenty-five years. The textile industry, steeped in tradition and prejudice, based on technology handed down from generation to generation, has at last called upon the aid of science in the solution of its technical problems.

A group of textile manufacturers in New England now support a cooperative research organization known as the Cot-

ton Research Company which, in its comparatively short period of operation, conclusively proved the value of research and the adaptability of its universal application to all types of industries. In England, under the government subsidy plan for the support of cooperative research, the Cotton Research Association was established in Didsbury, a suburb of Manchester. The entrance of applied science even at this late date, in a field which for centuries has been the backbone of industrial England, has done much to dispel the fallacy, existent for generations, that it was the "air of Lancashire which produced a superior grade of cotton goods."

The first director of research in one of the largest private laboratories was a physicist. To-day this association is supported by 95 per cent. of the producing industry, employs eighty-seven scientists, including specialists in every field of science basic to the industry, from botanists who study the various species of cotton plants, physicists who investigate the physical properties of the fiber, chemists who analyze its constituent elements, mechanical engineers who apply the scientific principles to the manufacturing processes, and finally industrialists who are responsible for the application of the results of research to full-scale commercial production.

The annual appropriation available for research, which is raised through an assessment prorated on the basis of the number of spindles in the mills of each member-company, is approximately $225,000 a year.

It is interesting to note that when the last word was written in textile history with the introduction of the Northrop loom in 1895, this same year marked the birth of an industry in this country which has come to take the first place in importance and size of all contemporary industries as listed in the recent U. S. Department of Commerce Census of Manufacturers.

The Automobile Industry

The automobile industry in America rests on the foundation of a patent granted to Selden, in 1895, which covered the principle of using an explosion engine in a road vehicle. The honor of being the first to make a successful gasoline automobile in America belongs to Charles B. Duryea. In 1900 R. E. Olds made the first type gasoline automobile. As late as 1903 Ford made the first Ford car of the present day.

The motor-car industry has taken full advantage of the possibilities of research organization. There are the General Motors Research Corporation laboratories serving as the centralized organization for that important group, the very considerable research organization of the Packard Motor Car Company, and the completely equipped automotive research units attached to the Studebaker and Dodge plants. The recently established research laboratory of the Ford Motor Company is a model in construction, design and equipment—a symbol of the important place which research occupies in that efficient organization.

There are four industries which have been developed from their basic invention to an important place in our present industrial organization, in a period of less than fifty years.

These are electric illumination, radio, electrochemical, and telephone. There is in each striking evidence of the interrelation of the "cycle of research" with the various stages in the development of each industry.

Electrical Illumination

Tracing the electrical illumination industry in briefest outline, we see the various steps pass in rapid succession, including the discovery of the principle of heating platinum wire to incandescence by Sir Humphry Davy in 1800; the experimental work on a carbon conductor in an evacuated glass bulb by the American, Starr, in 1841; the first suc-

cessful incandescent lamp developed simultaneously by Edison and Swan in 1878; the products of industrial research, the tantalum lamp in 1902 and tungsten drawn wire in 1906, which has now been adopted as the universal form; mass production is reflected in the figures of ninety million dollars paid for incandescent lamps in 1924. No stronger evidence of the benefits of research can be presented than the single fact that the cost of a given amount of light to-day is about 5 per cent. of what it was in 1880.

The Radio Industry

This lusty youngster cries out for recognition in raucous challenge among his elders, although he was ushered into the world but fifty-five years ago. His parentage was unquestionably scientific, since he was created from the stuff that science is made of—the involved mathematical formulas put forth by the English physicist Maxwell. But Maxwell's assertion that the ether of space transmits peculiar electric waves attracted little attention until, in 1890, Hertz startled the scientific world by demonstrating the truth of Maxwell's theory. Five years later Marconi gave the invention to the world in the first actual wireless telegraph and after a lapse of but a decade more wireless telephony was successfully tried for transatlantic communication by the technical staff of a great commercial company.

During the World War spectacular maneuvers were executed by squadrons of planes flying in formation on orders given from the ground by a wireless telephone. Within the last two years this device has been used for communication between ships at sea and commercial telephone stations. To-day radio is a successful connecting link with ships, with aircraft, across oceans and for reaching large groups of people as in broadcasting.

The development of radio for the automatic guiding of airplanes, torpedoes and even watercraft promises to have a spectacular and perhaps a very important future.

Electrochemical Industry

Aluminum was discovered in Germany in 1828 by Wohler. In 1855 it cost ninety dollars a pound. By 1886 it had fallen to twelve dollars. The American Castner process brought the price in 1889 down to four dollars per pound. Hall, in America, and Hersult, simultaneously in Europe, discovered that cryolite fused readily at a moderate temperature and when so fused dissolved alumina as boiling water dissolves sugar, and to the extent of more than 25 per cent.

The pure science or discovery period represented by Wohler was followed by the labors of others in applied research, which brought the development to the period of invention. In 1895 the manufacture of aluminum was started at Niagara Falls under the Hall patents. In 1911 the market price of the metal was twenty-two cents and the total annual production forty million pounds. By 1919 the production of aluminum had increased to two hundred thousand tons or ten times the amount in 1911. This latter statement indicates industrial application and suggests mass production.

One of the most important of the electrochemical industries is electrolytic refining of copper. To-day one of the forms in which the metal is most prominently available is electrolytic copper.

Electrolytic methods are also proving useful in the refining of precious metals. The extraction and refining of gold and silver, electrolytically, is assuming important proportions.

The problem of recovering tin from tin cans and other scrap is now carried out electrolytically. About 90 per cent. of tin in scrap is recovered in a form 99 per cent. pure, rivalling our old friend Ivory soap, which is claimed to be 99.41 per cent. pure. Electrolytic iron, which is used in considerable amounts in the manufacture of certain types of telephone equipment, also is very pure.

The Telephone

A classic illustration of research as an industry builder and the servant of man is the telephone. In tracing the development of this industry, three points are to be emphasized. First, that in the short span of forty-seven years, growth has expanded from a single telephone to a single concern which is rated as the largest industrial corporation in the world. Second that the research laboratories of the American Telephone and Telegraph Company, spending approximately ten million dollars a year for research, has been the largest single factor in this development. Third point is that its inception and subsequent growth was paralleled with the development of industrial research in the United States.

Forty-seven years ago there was one telephone in the world, the instrument which Bell invented. To-day there are sixteen million in the United States alone. At the time of its invention there were two telephone employees; to-day there are three hundred and fifty thousand. Forty-seven years ago the world's entire telephone plant could be held in the hand of one man. To-day with over sixteen million instruments in this country alone we have twenty-one thousand central offices, twenty-five million miles of wire and a total plant investment of two billion dollars. Last year the American Telephone system carried eighteen billion communications over a total distance of forty-five billion miles. Assuming that these messages were carried by separate messengers it would require the services of six million people, at a cost of ten billion dollars, to perform a task which the telephone company handles expeditiously with three hundred and fifty thousand employees at only a fraction of the cost. A few milestones in the path of research in this gigantic development may briefly be cited. The first paper insulated telephone cable contained fifty pairs of wires. Through concentrated development these were increased to one hundred in 1892; four hundred in 1900; and in 1912 to nine hundred. Two years later a twelve hundred pair cable was successfully developed, and even more recently fifteen hundred pair, or three thousand wires. This particular development has yielded a saving in the Bell system alone of one hundred million dollars.

Under the pressure of an increase in the price of tin used as a 3 per cent. admixture in lead cable sheath, a new sheath using 1 per cent. antimony was developed. In ten years this new formula has resulted in a saving of six million dollars. A new contact metal, used in relays and switches, to take the place of platinum, has paid a dividend of thirteen million dollars since 1916. Through the application of the phantom circuit principle to four hundred thousand miles of line, a saving of the order of eighty million dollars has been made. Without the use of loading coils, developed by research, it would have been necessary to resort to larger copper wires involving an additional expenditure of one hundred million dollars. Now we can see why in the face of advancing costs among the few remaining things that a nickel will buy are a car ride, the *Saturday Evening Post* and a telephone call.

Even in this sketchy outline of these industries there appears unmistakable evidence of the successive stages in the research cycle from the discovery in pure science to mass production in industry. It is significant that the time lag in these industries cited has been reduced to something less than fifty years. Now let us inquire into the nature of those factors which have been responsible for this phenomenal growth. The second fundamental principle is the relation of research to specific industries. This relation is quite definitely governed by five factors:

First, the rate of growth and develop-

ment of the industry itself. It is obvious that the older industries have to combat tradition and prejudice and continue with little change in processes because of a technology which is the accumulated experience of generations and which has become crystallized. A rapidly expanding industry, with processes in state of flux, with personnel coming to it with a fresh point of view is in the very nature of things progressive. As an example of one of the oldest industries, consider the fisheries, in which present-day methods of operation are fundamentally the same as two thousand years ago, as described in the incident on the Sea of Galilee, in which the fishermen were ordered to lower their nets for the catch.

Parenthetically, there is evidence that even the fisheries industry may enlist the cooperation of applied science in the solution of their technical problems. Within the past few months the division of engineering and industrial research has answered a request from the Middle Atlantic Fisheries Association for assistance in the organization of research in that field.

Second, the inherent technical nature of the industry. Obviously such industries as electric illumination, radio, electrochemistry, telephone and others of this general character were virtually born in the research laboratory—the seed of research is deeply rooted in the foundation of the industry itself.

Third, the character and number of technical personnel employed in an industry. A large cordage manufacturer in the middle west recently employed as a factory superintendent a man who had been trained as a chemical engineer and imbued with the research idea. On his first inspection trip through the plant he complained that the processes were archaic and immediately formulated plans for a research program and laboratory through the intermediary of a technical college in a nearby town.

Fourth, the position in foreign trade. As an illustration, out of the economic pressure of the World War a new industry was created for the manufacture of optical glass in this country. We had been entirely dependent on Germany as a source of supply for this commodity previous to that time.

Fifth, the character of processes and the present research facilities available to the industry. With these factors in mind, it is not difficult to understand the rapid development of the four industries last mentioned, since each encompasses from three to five of them. All are inherently technical in character, they employ large numbers of scientific and technical personnel, their growth has been rapid, their processes depend on scientific control rather than manual skill and they have developed during the era of industrial research.

While research is a primary factor in reducing the time lag in the cycle of development of an industry, it does even more than this: it not only affords technical superiority in competition between industries and provides an advantage to individual concerns within an industry which is competing with their fellows, but it is a dominating force in the present industrial age, since it creates industries and even destroys them—destroys in that it revolutionizes present processes, invents new ones and therefore may be the basic reason for the creation of a new industry or the specialized subdivision of the same.

The introduction of Methanol, the German process for the manufacture of wood alcohol, aroused fears in the wood alcohol industry of this country that an industry representing a capital investment of one hundred million dollars would be totally destroyed.

The reference to the Bell System Research Laboratories, the largest connected with a private company anywhere in the world, brings to mind an even more recent example.

The Victor Talking Machine Company had a business so highly profitable and so well organized that dividends on its common stock averaged more than forty-two dollars a share for eleven years, to which in 1922 was added a 600 per cent. stock dividend. Meanwhile research has developed the radio and the Victor Company has passed its dividend. You have all, no doubt, heard the new Orthophonic Victrola, but how many of you know that this new device is a byproduct resulting from fundamental research in the range and quality of the human voice, which was being studied for the amplification and improvement in quality and tone for long distance telephony in the Bell System Research Laboratories. Speaking technically, science created one device, and its byproducts, applied in another field, gave a new lease on life commercially to an industry which was threatened with destruction.

The third fundamental principle in the relation of research to industry is the period of the introduction of research and the accelerated development which follows. This effect has been described in several younger industries. What happens when research is undertaken in older industries? Let us take an extreme case—one of the oldest industries in recorded history.

The Iron and Steel Industry

Possibly the oldest piece of iron known was found in the great Egyptian pyramid "Gizeh," and is at least six thousand years old. Of primitive furnaces, one type, still used in remote parts, was successfully developed by the Germans in the Middle Ages, and is known as the "Catalan Furnace," because it was used in Catalonia, Spain.

In 1617 an Englishman, Dudd Dudley, was the first man to melt iron in a blast furnace with coke instead of charcoal. Abraham Darby in 1713 put Dudley's idea into practical form. In 1726 Corts introduced the rolling mill for rolling sheet iron. Huntsman, in 1740, devised the crucible process of making high-grade steel. In 1783 Corts developed grooved rolls for rolling iron bars and rods, and one year later he built the first reverberatory furnace. In 1828 Nielson further reduced fuel waste by heating the air of the blast. In 1856 Bessemer devised the process which completely revolutionized the steel industry. In 1857 William Kelly patented his converter, and in 1860 Siemens perfected the regenerative gas furnace. In 1893 the "Seven Merritt Brothers" turned over the greatest ore producer in the world. In 1898 Professor Sauveur, of Harvard, put forward his first iron carbide diagram, showing the eutectoid transformations and their relations to the heat treatment of steel. Note the period of introduction of research and the subsequent rapid development. In 1900 the development of high-speed steel by Taylor and White was first demonstrated in Paris. Vanadium and high-speed steel was introduced in America by Dr. J. A. Mathews, the present research director of one of our large steel concerns. Others were experimenting with it in Europe, but vanadium high-speed steel was first put on the market by an American company.

To indicate the development of the basic processes in steel making, in 1909 only .06 per cent. of steel was made by the electric process, while .4 per cent. was crucible. To-day less than .2 per cent is crucible.

The phenomenal growth of the steel industry is indicated by the fact that the production has risen to seven hundred pounds per capita in 1920 and one thousand pounds per capita in 1925.

This brief outline shows that the steel industry for hundreds, if not, thousands of years, was an art, and that within less than fifty years it has felt the influence of research and has experienced a greater development in that period than all the centuries preceding.

Now having briefly traced the historical development of five industries which have reduced the time lag from basic invention to full scale industrial application to less than fifty years, and have set up for comparison two industries which had their beginnings in earliest recorded history, what conclusions can we draw?

It is conceded that, in tracing the single threads in the pattern of our industrial fabric, warp, the body, is dependent for its strength on basic technology and technical improvement. The weft is an equally important component and may be influenced by such factors as economic pressure, commercial exploitation and even political and social forces.

From the record of the industries which have as the cornerstone in their foundations the invention of the incandescent lamp by Edison and Swan in 1878, the telephone of Bell in the same year, the first central station in 1882, the industrial application of Hall's patents in 1895, Selden's patents in the same year and Marconi's radio as late as 1900, we may submit the following:

First, all five industries—the radio, electrochemical, illumination, telephone and motor car—are inherently technical in nature, employ technical personnel, have had a rapid development and growth and production processes which are dependent upon technical knowledge rather than skill. These selected industries then include four of the five factors which I mention earlier which govern the relation of research to specific industries. Second, all five closely follow the successive stages in the research cycle. Third, at least two—electrochemistry and radio—were virtually created by research. Two of these industries—the automobile and the electrical—have taken first and third places, respectively, in importance and size among all industries in less than fifty years—certainly a minimum in time lag even in these days of high speed, automatic and mass production.

The telephone, although by certain standards not classified as an industry, deserves individual recognition. Emerging as an invention from the experiments of Bell, its individual development and application has produced the largest single industrial concern in the world. This enviable position has been attained almost wholly through the results of research. The security of its position based on a monopoly has been maintained by the backing of the largest research organization in existence attached to a private enterprise. In a thirteen-story building entirely devoted to research, the Bell System Research Laboratories employ over three thousand people. These include scientists, engineers and technicians, all engaged in the solution of technical problems arising in the field of communication.

Here the time lag in the research cycle is reduced to the absolute minimum, since within this organization, personnel, equipment and supplies are available in each stage of the complete cycle from "discovery in pure science" to industrial application and the preparation for mass production. This does not mean, of course, that inventions are made and reduced to practice over-night. Long and careful tests must be made of new devices in actual service.

There remains but one of the first groups of industries to consider, namely, electrical illumination, since the development of this industry in its major aspects is a parallel to that of the telephone. Although the initial impetus may be credited to Edison's first successful incandescent lamp, the widespread industrial application in the present universal form dates from the drawn tungsten wire of the pure science research laboratories of the General Electric Company. The development of the present Mazda lamp, as it is known, was carried through the complete research cycle under the supervision of this research unit. Even today the laboratory exercises a quality

supervision over the manufacturing units through a system of scoring based on defects. The cost of present-day lighting speaks volumes in testimony of research as an industrial aid.

Of the two industries in the second group—the textile and iron and steel industries—even in the comparison of the bare outline of their development it is apparent that it has taken centuries to accomplish in them what has been done with the aid of research in decades in the first group.

The iron and steel and textile industries until comparatively recent times were arts as distinguished from scientific industries dependent upon skill rather than technical knowledge, employing artisans rather than technicians, and were handicapped by tradition, prejudice and human frailties handed down from generation to generation. At no point, except within very recent years, did science touch the course of their evolution. Processes and tools were the inventions of skilled practical artisans and mechanics. A detailed analysis will indicate that they do not contain a single element of the factors which encourage the development or utilization of research.

We may have been so intent upon examining the details of our picture that we have overlooked the importance of the development period of industry as a whole in the last century. The boring mill of Wilkinson was perfected in 1774 and used to bore the cylinders for Watts steam engine; Maudsley, during the period of 1771–1831, developed the slide rest for metal-working, screw-cutting tools, and laid the basis for the lathe, the planer and the plotter.

Of this period, Roe in "English and American Tool Builders," says, "By 1850 mechanical equipment was substantially what it is to-day; in fact, most of this change came in a generation, the period from 1800 to 1840."

Within the last forty years this new factor, industrial research, has considerably altered the foundations of the industrial structure. Generally speaking, there are three types of industries or businesses.

Measured by modern standards each depends to a greater or lesser degree upon research. The most successful industry or business from the standpoint of earnings rests upon a monopoly. A patent is a seventeen-year monopoly granted the inventor for his ingenuity and work. Even professional men of outstanding eminence, who command large fees because of their prestige or skill, or because they can do something no one else is thought to be able to do, are monopolists in a sense.

Next in strength is the industry or business enterprise founded on strategic position, the only factory of its kind in the district, a store on the corner of two main thoroughfares, the warehouses built on the waterfront of a city which grew. Such businesses are less certain profit producers. They are more dependent upon chance, efficient management and upon service rendered.

The third type is formed on service and popular appeal, such as a department store, a hotel operating under highly competitive conditions. In this type of business, effective management, novel publicity and popularity are vital necessities.

Research to insure the safety of invested capital is essential to the first type of industry. Research to maintain a strategic position is essential in the second class, and research to secure every advantage in the fight for survival is vital to the third class.

The extent to which research has developed as a recognized and valued industrial aid in about forty years is indicated by this statistical data. We are spending approximately $100,000,000 a year for industrial research in the United States. The government, with its many scientific technical bureaus and research agencies, attached to practically every department, is

spending approximately one third of this amount, while industry is matching dollars for research two to one for the government expenditures. A recent survey in research indicated that the federal government was engaged in five hundred and fifty-three separate cooperative projects, three hundred and sixty of which were research involving altogether eleven hundred cooperative undertakings. The federal agencies engaged in research include some twenty-three bureaus. There are nearly six hundred industrial research laboratories in the United States exclusive of government and university research agencies. Fifteen individual industrial companies from which reports are available are spending in the aggregate for research between twenty and twenty-five million dollars. Some thirty trade associations are spending approximately twelve million a year. Research in the universities, institutes and technical colleges have assumed considerable proportions especially in such well-known ones as Carnegie Institution, Massachusetts Institute of Technology, University of Illinois, Purdue, Mellon Institute, Cornell and many others.

How important this is may be judged from the "Waste in Industry" report of the American Engineering Council, which placed the average waste in our industries at 49 per cent., 70 per cent. of this being chargeable to management.

The lack of appreciation of the importance and value of research compared to other recognized industrial aids such as advertising, statistics, publicity, etc., is indicated by the fact that we are spending eleven dollars per capita for advertising, five dollars for jewelry, twenty-seven dollars for joy riding, pleasure resorts, etc., eleven dollars for candy, twenty-one dollars for automobiles and parties, and eighty-seven cents per capita for research.

The reader's own judgment may strike the balance between the service and return of these items with which we are familiar, in comparison with that from research, which several reputable industrial companies have authoritatively stated as from five to ten to one for the investment involved.

A Department of Commerce expert has figured the annual loss in waste in American industry at thirty billion dollars. It would seem that the expenditure of one third of 1 per cent. of this amount for research is absolutely inadequate.

When we consider that half the population of the United States carries average life insurance of $1,300, it would seem that American industry can afford considerably to increase its premium in insurance against waste and ignorance. Annual insurance premiums are paid for such remotely removed catastrophes as tornado, windstorm and cyclone, to the amount of twenty-six million dollars, and combined marine insurance of approximately sixty-four million dollars—three items which total the approximate amount spent to improve the basic technology of our industries.

Several industrial leaders recently have sounded a warning of the foreign competition that America will have to face in the next few years. Tariff walls or other political or commercial devices will not prevail against the technical superiority of European nations which long have had research solidly entrenched in their industrial organization.

In England, the British government, through their subsidy plan, has appropriated five million pounds to encourage the establishment of cooperative research associations in various industries. At present there are twenty-six active research associations operating under this plan in which the industries match pound for pound the appropriations of the government.

In France the government allows industrial concerns to deduct from their income tax a percentage of the funds appropriated for research. A bill which recently passed the Chamber of Depu-

ties provides a tax of five centimes on each one hundred francs paid in salaries. It is estimated that seven hundred thousand dollars annually will be raised by this means for the support of scientific research laboratories.

In Germany industrial research amounts to almost a creed. Its supremacy there was heralded throughout the world before the war. It made a lasting impression during that struggle, and is at the moment being organized for competition in the world of trade.

Are we prepared to meet this foreign industrial competition? What specific proof can be presented which will vitalize the broad generalities previously mentioned with concrete realities? What are some of the outstanding research achievements of representative laboratories? To what extent has the "time lag" in the "cycle of research" been minimized?

A cross-section of the more recent research projects, together with an indication of the period of the cycle from discovery or conception to commercial production, is suggested in these answers to my inquiry. From the General Electric Research Laboratories:

Loud Speaker

1922 preliminary study of factors; 1923 resulted in crystallization of certain ideas for loud speaker designs and later in the same year development of present type began. Laboratory and engineering development was completed by the spring of this year. Quantity production was begun early this fall.

From the report of A. D. Little research organization this development in fuel research is quoted:

New Vaporphase Process for cracking Petroleum

Three and a half years ago the general conception of the process came to them, since then the research has passed from the small laboratory scale to large-scale laboratory operation, then to a semi-commercial plant with a daily output capacity of eight barrels of oil, then to one of twenty-five barrels, and finally to the design and construction of a three hundred and fifty barrel unit, which they expect to bring into operation next January.

The General Motors Research Corporation added this evidence of research in paint:

Duco

1920 DuPont people learned how to increase the total solids of duco many times without making the material too thick to apply. 1921 they brought their problem to General Motors and they helped with commercialization of the conception. 1923 first cars finished with Duco were put on the market by Oakland.

In electrical research the Westinghouse Electric and Manufacturing Company cited this project:

Lightning Arrestor

Early in 1921 one of the engineer physicists conceived the idea of using a certain electrical phenomenon as the basis of a lightning arrestor. Preliminary tests were made and his theory was established. Research work was undertaken, preliminary construction and tests were made and experimental field units were put out in the fall of 1921. 1923 commercial production was undertaken. 1924–1925 quantity production.

The director of research for the E. I. du Pont de Nemours Company covered several phases of chemical research and explosives:

Improvements made and New Developments

Safety explosives for use in coal mines to prevent explosions due to ignition of coal dust and mine gases have been developed, and du Pont Company has developed a complete series of non-freezing high explosives, which have been a very great advance in the art owing to the large number of accidents which were caused in former times by the thawing of high explosives containing nitroglycerine. Most recent development in smokeless powder manufacture is a progressive burning powder for shotgun uses which has the quality of giving higher velocities with lower pressures and higher shot loads. Du Pont Company has also developed in the last few years some very important seed disinfectants which seem not only to have the property of destroying disease germs on the seed, but also aid the propagation and the growth of plants in their early life.

The Bell System Research Laboratories reported somewhat more generally to this effect:

Of the products of the research and development work of these laboratories there may be mentioned: machine switching telephone developments; multiplex transmission—telephonic and telegraphic by carrier currents; the development of various types of loud speakers including the most recent cone; of phonograph methods of recording and reproducing; apparatus for the study of speech by harmonic analysis, and of hearing by audiometers, and of relief of partial deafness by audiphones; applications of these developments to the amplification of heart sounds and to their phonographic recording; the entire group of contributions of the laboratories in the way of elements and systems for radio; and various electronic appliances like the cathode-ray oscillograph and the ionization manometer. All of these have reached standardized forms and mass production within recent years.

This glimpse through the door of a few representative research laboratories is reassuring. Here is conclusive evidence that our research organization is geared up to the present speed of industrial progress, and here are several instances in which the "time lag" has been reduced to a period of less than five years.

There remains but one question to be answered. Does research pay dividends?

To answer that question is to consider the relative growth, development and earning capacity of representative industrial corporations as reflected in income taxes paid by the first ten concerns reporting at the last period.

Among the first ten names which are synonymous with large and completely organized research departments, are the Ford Motor Car, American Telephone and Telegraph, United States Steel Corporation, General Electric, General Motors, Standard Oil, New York Central, Consolidated Gas, Union Pacific and Reynolds Tobacco Company.

Seven of the first ten have as an essential part of their production units research laboratories of international reputation. The total income tax paid by these ten concerns is approximately seventy-five million dollars, or three quarters of the aggregate expenditures for research in the United States.

In these figures we see the final appraisal of the value of research, a real measure of industrial progress, the ultimate stage in our research cycle, an indicator of the speed at which the main rotor in the prime mover is turning.

To act as sponsor in organizing the resources of science for the solution of the technical problems of industry is in effect a broad statement of the purposes of the Division of Engineering and Industrial Research of the National Research Council.

Since another function of the division is concerned with engineering, we may perhaps through that experience be able to insert a gear in the engines of industrial progress which will still further reduce the "time lag."

This increment of acceleration in the "research cycle" will be transmitted through the whole train of economic, industrial and commercial mechanisms, since they are geared directly to "Research—the Prime Mover of Industry."

Author's Note: Grateful acknowledgment is made to the authors of "Profitable Science in Industry" which was freely used as reference. Also to the Research Laboratories mentioned in this paper.

PSYCHOLOGICAL METHODS TO PROMOTE HIGHWAY SAFETY

By J. McKEEN CATTELL

PRESIDENT OF THE PSYCHOLOGICAL CORPORATION

JUST forty years ago there were published by me the first psychological measurements of individual differences, based on experiments made at the Johns Hopkins University and the University of Leipzig. These experiments were of two kinds. On the one side exact measurements were made of the time of the reaction of different individuals to various signals and situations, including the effects of fatigue and distraction. On the other side series of tests were used in which with pencil and paper the individual met certain situations, and the time and correctness of the answers determined what is now usually called "general intelligence." These experiments were made in the laboratory ten years before the invention of the automobile and are one of many examples of how scientific research may ultimately prove to be of practical use. The driver of a car needs to react quickly and correctly to the situations that he meets on the road and without disturbance from unforeseen happenings or emotional excitement. He must have a certain amount of common sense and intelligence, in order to be able to drive without causing inconvenience or risking injury to others.

We need to use psychological methods to determine how well an individual can drive a car and in so far as possible to predict how well he will be able to learn by practice. It is not nearly so dangerous and difficult as was once supposed; but it is obvious that in ability to drive individuals differ greatly, partly by varying natural aptitudes, partly by amount and kind of experience. Those who can not drive on the highways without inconvenience and risk to others should not be permitted there. If an individual has only moderate aptitude he should take this into consideration in deciding whether to buy a car, to drive it under difficult conditions, to take out his wife and children. Unless he has more than average natural ability, he should not take up motor car driving as a calling.

Psychological tests that can be made in three hours predict whether or not a boy is likely to do well in college. For a considerable percentage of those examined the writer is prepared to pay the entire college expenses if the student gets the degree, in case the father will pay an equal sum in case he fails. If each boy and girl were tested at the age of sixteen, it would be possible to predict with a reasonable degree of accuracy where he would stand among all automobilists who had, say, driven 10,000 miles, after he himself had driven that far. He might do better or worse than the test predicted, but on the average the prediction would be correct within certain limits. Such a test would only take the time and have the cost of half a day at school; it would be far more useful as a factor in education, apart from the valuable information that it would give.

Every ability is to a certain extent special and at the same time has factors common to other abilities. We can

make a threefold classification that is useful. There is the logical ability to reason and deal with abstractions, which can be measured by the way in which an individual handles numbers and words. There is the objective ability to deal with things, machines and concrete situations, which can be measured by suitable methods and apparatus. Lastly, there is the social ability to get on well with other people, which has only recently been taken up by psychologists, but in which we expect rapid progress in the near future. Thus it has been found recently by the Psychological Corporation that more than seventy per cent. of typists applying for a given position would cheat when given the opportunity without apparent chance of detection.

The man who drives his own car requires a certain minimum abstract intelligence, but perhaps only enough to stand above the lowest 10 per cent. of the population. He requires relatively more mechanical ability, though less than was formerly supposed. The question of social ability is still open, but it is important. Proper regard, not only of the rights, but also for the convenience and welfare of others, is a factor scarcely considered. A driver may have ample intelligence and unusual skill, but may be inconsiderate and careless, or may take chances to an extent that makes him unfit to use the public highway.

Licenses for Drivers

A license should be required for every driver of a car, if only as a means of identification, but the examination should be simple and easy to administer. Special attention should, however, be given to professional drivers, to those suffering from disabilities which may interfere with safe driving, and to those who have had accidents or have been convicted of serious offenses against the motor laws.

These are recommendations made by a sub-committee, of which the writer is chairman, to the Committee on Causes of Accidents of the National Conference on Street and Highway Safety arranged by the Secretary of Commerce. They have been adopted by the committee and will be brought before the conference at its approaching meeting. It is proposed that applicants for licenses to operate motor vehicles on the public streets and highways shall be divided into four groups who shall be given examinations as follows:

Group A. Applicants for licenses to drive private cars who shall be given an examination that will yield the best results in a limited time and shall be comparable in all jurisdictions.

Group B. Public chauffeurs, including drivers of taxi-cabs, busses, trucks and emergency vehicles, who shall be given a more difficult and searching examination.

Group C. Applicants suffering from some disability such as defective eyesight or hearing, loss of limb, old age, illiteracy, a record of insanity or conviction of crime, who shall be given a special examination.

Group D. Those who have been responsible for accidents resulting in personal injury or considerable property damage, or who have been convicted of serious offense under the laws governing the use of motor vehicles, who shall be given a thorough examination before their licenses are permanently renewed.

The subject is of such general scientific and practical importance that it may be desirable to review the grounds for these recommendations and the psychological methods that the writer regards it as desirable to use in order to eliminate the incompetent driver of motor cars and thus to increase the safety of the highways.

Applicants for Licenses to Drive Private Cars

Owing to the fact that the number who apply for licenses to operate motor vehicles is very large, it is necessary that the examination be as simple as possible. It seems to be desirable, therefore,

that in addition to information on the application form the examination shall consist only of an information test and a road test.

The application form should be drawn up with care and made the same in all jurisdictions. It should record the age, sex, place of birth and legal residence of the applicant, and—for purposes of identification—the height, weight and color of eyes and hair. For the latter purpose consideration might be given to requiring in addition to the signature a photograph or a fingerprint impression. The applicant should be asked whether he has been responsible for any accident causing personal injury or involving damage to the property of others to the apparent amount of $10, and whether he has been fined or imprisoned for any offense against the motor laws or involving the use of motor vehicles. If he answers in the affirmative he should be referred to Group D. When a motorist is arrested for any cause the records should be examined and any one who has committed perjury on his application blank should be prosecuted. The only other question recommended is whether the applicant has any defect that seriously interferes with driving a car. If he answers yes, he should be transferred to Group C for a special examination. If he answers no and is later arrested and proved to have a serious defect he should be prosecuted for perjury.

Questions should be avoided that can not or will not be answered correctly by the applicant. Thus if normal eyesight and hearing are required, the tests, which can be made in ten minutes but require expert knowledge on the part of the examiner, should be made. Applicants can not answer questions such as are asked in some jurisdictions; almost every one has eyesight or hearing defective to some extent, and an answer "yes" or "no" conveys no information useful in deciding whether a license shall be granted. The applicant should be watched for possible disabilities in the road test and in case he exhibits or gives indications that he has any serious defect he should be transferred to Group C for a special examination. It is futile to ask whether the applicant uses intoxicants or drugs. It is not useful to inquire the number of years or the number of miles the applicant has driven, for it is likely to be answered incorrectly; if he passes the tests in a satisfactory manner the smaller the mileage he has driven the more likely he is to become a competent driver. A similar situation obtains in reference to a requirement that the applicant shall have driven at least a hundred miles under guidance. It would require an expert examiner to evaluate such a factor as this. It should be a credit if he passes a good road test after having driven only a few miles, a demerit if he passes a poor test after a large mileage.

The information test should consist of printed questions designed to discover the applicant's knowledge of the laws and traffic regulations which he is expected to obey, his judgment in operating a car, and his ability to recognize difficult, dangerous or illegal situations. There should be a uniform test that will be of equal difficulty at all times and at all places. Such a test prevents favoritism and determines just where the applicant stands among those who are examined.

In addition to the written information test there should be an individual road test which should also be standardized so that it could be reported, *e.g.*, that an applicant stands in the upper fifth or lower tenth of all applicants. It is also important to avoid favoritism or different methods of examination. For a standardized examination a testing yard would be desirable, laid out so that the applicant would drive and turn within

definitely marked lines, stop and start on an incline of 15 per cent., avoid obstacles, follow road signs and park within a given area.

Accidents undoubtedly occur through the use of different cars by the same driver and the gear shifts and other mechanisms should be standardized for all cars, by legal enactment if that proves to be necessary. It is, however, probably not useful that a license be given to drive one make of car only, as a competent driver of one car can learn to operate another in a short time, and unnecessary and irritating restrictions that are likely to be violated should be avoided. It seems unnecessary that questions be asked concerning the mechanism of the car or repairs on the road, as these do not seriously affect highway safety.

It is not feasible that there be an examination each year for the renewal of the license. In time and money of the applicant and of the examiner it would cost over a hundred million dollars a year to reexamine twenty million motorists. There should, however, be an application for renewal each year and the applicant should be required to report any accident causing personal injury or property damage amounting to $10 in which he has been involved, and any fine or conviction under the traffic laws. Motorists who stand in the lower tenth or fifth of those passed in the examinations might be given a temporary license for one year and be re-examined before renewal.

Information concerning traffic rules is so easily acquired for an examination and so readily forgotten afterwards, the practice and ability needed to operate a car in a simple test are so small and so useless in an emergency, and the difficulty of securing competence and fairness in the examination so considerable, that it is quite possible that it would be desirable to give consideration to waiving a formal examination and only requiring the applicant to declare under oath that he had studied the laws and regulations and is competent to drive a car on the road, the statement perhaps being affirmed by two witnesses. In the future a thorough physical and psychological examination for a license may become desirable, but it appears that there is no more danger in operating a car than in driving a team of horses under the same traffic conditions. In general no restrictions should be placed on individual liberty which are not required for the welfare of others, but each should be held strictly accountable for the results of his actions. Strict examination should, however, be required for public chauffeurs, applicants having defects or handicaps, and those involved in accidents or convicted of offenses.

Professional Drivers

There should be a more thorough and difficult examination before a license is granted to professional drivers. These include drivers of taxi-cabs, delivery wagons, busses and trucks; chauffeurs in the public service and private chauffeurs when a special license is required; drivers of school busses or cars; drivers of emergency vehicles, such as hospital ambulances, postoffice wagons, police wagons and fire patrols. These drivers are fewer in number and a careful examination is consequently feasible. They continually use streets and roads maintained by taxation and needed by pedestrians and by other drivers. They may have right of way, the waiving of a speed limit and other privileges. They may operate vehicles especially liable to harm the roads and to cause personal injuries or property damage. The state has a certain responsibility such as it undertakes in licensing physicians, pharmacists or barbers.

It might be assumed that the public services and large corporations would arrange in their own interest for special examinations and this is now being taken up for the Postoffice Department and by some taxi-cab companies. But in most cases the number of drivers concerned is too small to warrant special examinations by the employer and some corporations would prefer a public examination in view of their relations to their employees. It is also the case that in a matter that so greatly concerns the public welfare the state should maintain its authority. For example, a taxi-cab company that has special examinations which show that accidents are more than twice as frequent for those who do not pass them none the less waives the examination when there are not sufficient applicants.

Character of Examination

For professional drivers the information blank should be more complete and the written examination and road tests more exacting. The applicant should be required to give full information concerning his record and history, his habits and defects, and should be held strictly accountable for the correctness of his replies. In the written examination and in the road test, ordinary knowledge and skill should be assumed and a thorough examination given to ascertain that the applicant is expert in knowledge of laws and regulations and in ability to meet conditions of traffic with special reference to the vehicle that he will operate and the condition under which it will be used.

In addition there should be physical and psychological examinations. Eyesight and hearing should be tested and probably color blindness. It is not recommended that color blindness, from which about one man in twenty-five and one woman in a hundred suffers, should be a disqualification for the ordinary license, but in the case of professional chauffeurs it should be given careful consideration. The same situation holds for imperfect hearing, high blood pressure, liability to fainting fits and other disabilities which may be the cause of accidents.

It is further recommended that there be a psychological examination of general intelligence which, however, can be combined with the information and operating tests. Those of such low intelligence that they would be classed as morons and would not be accepted as army recruits should in the interest of public safety not be allowed to be public chauffeurs. There should also be a psychological test of quickness and accuracy of response to the situations that the driver will meet, including his presence of mind under disturbing conditions. Such tests can be made while the vehicle is being operated, but they can be made more accurately, quickly and with reference to ability rather than to practice with special apparatus and laboratory methods. Carefulness also can be determined. If there is a testing yard the driver's skill can be determined by requiring him to drive as quickly as he can ten times around a circle or oval, keeping within a marked track. One section of the track can be oiled so that skidding must be avoided. If the driver is quick and at the same time keeps within the lines he is a good operator, if he is both slow and inaccurate he is incompetent, if he is quick but crosses the lines frequently, he is careless or reckless, a quality to which special attention should be given. Similar results can be obtained from tests with laboratory apparatus. There are other qualifications that professional chauffeurs should have, such as the efficient and economical use of the car and ability to make repairs on the road, which mainly concern the employer but are not irrelevant to public safety.

The importance to the public safety and the responsibility assumed by the state in granting licenses to public chauffeurs may ultimately make it desirable to require as a prerequisite a course in a special school which grants a diploma based on a definite course of instruction. In that case a temporary license might be granted subject only to annual renewal after re-examination until the chauffeur has obtained a professional training.

Handicapped Applicants

There are various defects and handicaps which interfere with driving and the safety of the road. They may be comparatively slight but always present, as hardness of hearing; or unlikely to occur but serious if they do, as an epileptic fit or a stroke of apoplexy. Those suffering from defects of this character are not fit to be professional chauffeurs, but it does not follow that they should be forbidden to drive their own cars under suitable conditions. During the war recruits were rejected if they were shortsighted, even though in spite of this defect many of them would have made better soldiers than one half of those enlisted.

In some jurisdictions deafness or the loss of a limb debars an applicant from a license. It can, however, be argued that the greater care likely to be exercised by a man who is deaf will more than compensate for this defect; his liability to accidents can only be determined by a careful statistical investigation. In any case a man who is deaf and is at the same time of high intelligence and an expert operator is a safer driver than one with normal hearing, but standing in the inferior group to which licenses are granted.

The proper method, as indeed in granting any license after a careful examination, is to have a scale of merits and demerits. Thus 100 should mean that a man is in the first one per cent. of all adults in his intelligence, skill and other qualifications as a driver. If it is decided after scientific investigation and review that the least competent thirty per cent. of the adult population (including defectives, criminals, the feeble-minded, the illiterate, the aged, etc.) are unfit to drive on the public roads, then a percentile grade of 31 would be the lowest qualifying for a license. These grades have what is technically known as a probable error which can be determined. It might be in the neighborhood of ten places low in the scale which would mean that the chances are about one in four that the applicant graded 31 is among the 20 per cent. of the population least competent to operate a car and that the chances are nearly even that he is worse than the 30 per cent. fixed as the lower limit for licenses. It is these considerations that have led to the suggestion that those who stand low in an examination shall be given a license for one year only and then be required to repeat the examination.

This point percentile system can be used to special advantage in the case of the defective and handicapped groups. For example, if it is guessed now or determined later that 20 points, adjusted from the middle of the scale, is the handicap of a man who has lost his left arm, then if he stands in the upper half of those passed in his other qualifications he should be granted a license, if he stands in the lower quarter it should be refused. The quantitative deduction for any handicap can be estimated approximately or determined by scientific experiments. Thus if total blindness or technical insanity are assigned a demerit of 80 graded points, no one having one of these defects could obtain a license whatever his other merits might be.

If an applicant is so illiterate that he

can not read road signs he is refused a license in some jurisdictions, but consideration has scarcely been given to those who are not illiterate but who can not read English. Those who can not read or understand the written examination in the ordinary test might be referred to Group C where they would be given a more thorough examination and their handicap duly weighted.

An insane asylum or recent prison record, drunkenness, or liability to a disease such as epilepsy should be regarded as serious handicaps and licenses should rarely be granted to those who suffer from them. This can be adjusted by the system of merits. For example, recent conviction of a serious crime such as robbery or rape with the use of an automobile should give a demerit of 80 or 100 graded points which would be prohibitive. Conviction some years previously of a crime such as forgery would give a smaller demerit.

The Age Handicap

The age handicap deserves special consideration. The committee on uniform laws recommends a limit not lower than sixteen years and in some jurisdictions the limit is higher. We do not at present know whether or not a boy of seventeen or of fifteen who passes an examination as good as that of a man of fifty is or is not more likely to have an accident or to violate the laws and regulations, but this could be determined by adequate experiments or statistics. If a boy of seventeen or of fifteen is not more likely, or even if he is only slightly more likely, than an adult to be involved in an accident he should with the approval of his legal guardian be given a license on the same conditions as others. It is undesirable to have useless restrictions that are likely to be violated, and the earlier an individual learns to drive the better driver he will probably be in later life. Thus the granting of licenses at a comparatively early age may lessen accidents in the future. We are concerned with the psychological and mental age of a youth rather than with his calendar age. A boy of sixteen or seventeen may be as competent with a car and in all the affairs of life as the average boy of eighteen. If the lower limit is eighteen a license to drive under special conditions at an earlier age should be granted as it now is in New York state. It would also seem reasonable that a youth under the legal age might with the approval of his guardian be referred to Group C and be given a special examination for mental age and qualifications to drive.

The older ages have not hitherto been a serious problem, because owing to the recentness of the automobile and especially of its extensive use there are but few old drivers. We have as yet but little scientific knowledge regarding the situation after middle life, but it is evident that after a certain age a driver will become less competent and may become altogether incompetent. It may be desirable that after an individual reaches the age of sixty his license should not be automatically renewed, but that he should be referred to Group C for a special examination.

Drivers involved in Accidents or Violation of the Law

It appears probable that most accidents causing personal injury or property damage are due to a small proportion of all motorists, as are also a majority of infractions of laws and regulations. It consequently appears to be highly desirable that those involved in accidents or convicted of other than trivial offenses should be required to undergo a special examination for competency, such as is recommended for professional chauffeurs and handicapped classes, with such further examination of the individual and of the circumstances as may be desirable. If the accident or offense is serious the license should be suspended until the examina-

tion has been held and a thorough investigation has been made of the causes and circumstances of the accident or offense; if the accident or offense is not serious, the license should be continued provisionally for 30 days, or until the examination and investigation have taken place.

It may be that such an examination should be required only after a second accident or offense, especially if the first is not serious, but it is difficult to obtain the record of previous accidents, and no one who is competent and careful should object to such an examination. It is urgently needed in the interest of public safety for those who are incompetent or reckless. The time required for an examination and the payment of its cost would be a reasonable penalty and would be an extremely useful and quite feasible preventive measure, leading all drivers to take greater care to avoid possible accidents or serious infringements of the law, such as reckless speeding, which may be the cause of accidents. An incidental advantage of a thorough examination of those involved in accidents and of the circumstances is that it is the best way to obtain knowledge concerning the causes of accidents and the means of preventing them.

General Considerations

The regulation of motor traffic on the public streets and highways is a problem of the utmost complexity and importance. While statistics are not altogether adequate it appears that there are about 22,000 deaths and 700,000 personal injuries a year caused by motor vehicles. The damage to property is very large. The number of warnings, arrests and convictions, sometimes only for violation of regulations adopted for general convenience, but frequently for offenses, putting life, person and property in jeopardy, is unknown, but is very large. About ninety per cent. of all accidents with motor vehicles are due to the human factor. It is reasonable to estimate that deaths, injuries, property damage and offenses might be reduced to one half and perhaps to one fourth, if the best methods for licensing drivers of motor vehicles and for controlling motor traffic were adopted and these methods were perfected by further investigation.

It should be remembered that the pleasure, advantage and economic value of motor vehicles are enormous, the service that they render being of use to practically every one. Due largely to improved methods of control and systems of licenses, deaths and accidents are increasing more slowly than the total traffic. In fifty-seven cities with an aggregate population of about twenty-seven million, nearly one fourth the total population of the country, there were reported 4,827 automobile fatalities in 1923, 4,992 in 1924. Deaths and disablements from motor vehicles are small compared with those from influenza and colds, and there are no compensating advantages in the case of the colds.

Laws and regulations should only be made when on the one hand the benefits are greater than the drawbacks, and on the other hand when they are supported and likely to be enforced by general public sentiment. Owing to the vast importance and the newness of the subject arrangements should be made for thorough scientific inquiry and investigation continuing over a period of years. This should be under the auspices of the Department of Commerce which has initiated the work, with funds appropriated by the federal government for the purpose, given by public-spirited associations, foundations and individuals, or contributed by makers of cars, insurance companies and others who profit from the use of motor vehicles under the most favorable conditions.

AROUND THE WORLD IN A DAYLIGHT DAY: A PROBLEM IN FLIGHT[1]

By Dr. CHARLES H. T. TOWNSEND

ITAQUAQUECETUBA, ESTADO DE SAO PAULO, BRAZIL

WILL the possibility suggested in this title ever become reality? It seems probable that this question may be answered in the affirmative. The airplane practically owes its existence to a study of the problem of flight among the lower animals. May not a more complete study of such flight, therefore, result in attaining whatever speed is an accomplished fact among them? There seems to be no mechanical reason why this hope should not be realized.

What is the swiftest flight known among the lower animals? Bird flight has posed as the usual model in air studies, but we must evidently turn to the insects and among them to the flies if we are to look for a demonstration of the highest rate of speed. The swiftness of flight of certain birds seems almost without rival, but certain flies exceed even their remarkable speed.

The flies of a muscoid group, represented by the genus *Cephenemyia* of North America and Europe, but also including several other genera, evidently hold the world's record for high speed in flight. This is the more strange since these flies take no nourishment whatever in the fly stage. All the feeding of *Cephenemyia* and its congeners is done in the larval stages, the larvae being parasitic within the nasal passages and other head or throat cavities of various species of deer and allied ruminants. It is apparent from this fact that *these flies carry a tremendous supply of stored power in extremely reduced bulk and weight.*

Swiftness of flight is a prime requisite in the economy of these flies, enabling the females not only to scour immense tracts of country in their search for suitable host animals, but also to overtake them when found and deposit larvae in their nostrils. The male *Cephenemyia* flies frequent high and bare mountain tops; the females usually frequent the haunts of their hosts and always so after fertilization. They have much the appearance of bumblebees in both size, form and color, but are of a slighter build. They live many weeks in the fly stage and can doubtless maintain their swift flight for hours at a time. It has so far proved impossible to capture them in full motion. The few specimens known in museums have been either taken while alighted and warming themselves in the sun, captured during minimum activity at temperatures below the optimum or reared from larvae secured from the host animals.

Can the speed attained by *Cephenemyia* in flight be calculated with any degree of accuracy? The writer has endeavored to do this, having repeatedly witnessed what he considers both males and females of this genus in full flight. In extended flight their passing is of such an incredible swiftness that one is utterly unable to initiate any movement whatever toward capture before they vanished from sight. Form is not sensed by the eye as they pass, but merely a blur or streak of color and only a fleet-

[1] Read before the Third Pan-American Scientific Congress at Lima, Peru.

ing glimpse of that. It may be safely estimated, in the opinion of the writer, who has given much thought to the subject, that *these flies attain a speed upward of 400 yards per second.*

If it were possible to drive an airplane at this speed for seventeen hours at a clip, the feat suggested in our title could be accomplished. Let us verify this assertion, for it is worth while to examine this matter, however stupendous it may appear. The distance around the earth on the 40th parallel is 13,855 miles. At slightly less than 400 yards per second, we should accomplish 815 miles per hour or 13,855 miles in seventeen hours, on a nonstop trip from early dawn to late twilight of a summer's day.

Setting out from New York at 4 A. M., we could take *coffee* over Omaha, *breakfast* over Reno, *tiffin* over Peking, *tea* over Constantinople, and *dinner* over Madrid, while arrival in New York at 9 P. M. would complete the circuit. Here is the tentative approximate schedule:

rate of speed by discovering all the mechanical principles involved. Is not such an investigation well worth trial?

Increased strength and elasticity of materials with reduced bulk and weight of power are the problems now confronting aircraft evolution. Heavier-than-air machines can evolve no farther until these essential problems are solved. Their solution has already been attained in *Cephenemyia,* as has also the solution of the high speed problem, hence a full study of the manner of these solutions is all-important. The airplane, in its present stage of evolution, is capable of making the above 40th parallel circuit of the earth in a trifle over fifty-five hours, provided the present highest average rate of speed (250 miles per hour) can be continuously maintained for that length of time. Multiply by three the highest speed yet attained (266 miles per hour) and we approximate *Cephenemyia,* with the above daylight-day circuit in sight.

But speeds grow gradually and before

New York to	Miles	A. M. Leave 4	Meals	Distances between points	Hours between points
Omaha	815	5	Coffee	815 miles	—1 hour
Reno	1,630	6	Breakfast	815 "	1 "
Peking	6,520	12 M.	Tiffin	4,890 "	6 hours
Constantinople	9,780	4 P. M.	Tea	3,260 "	4 "
Madrid	11,003	5:30	Dinner	1,223 "	1½ "
New York	13,855	Arr. 9 P. M.		2,852 "	3½ "

Such a feat as the above would cause Jules Verne's illustrious shade to blanch and pale. Even his fantastic imagination could scarcely conceive such a spectacular outcome as here suggested. But the facts are already written in insect economy and why may we not copy them? Quite probable it is that an exhaustive study of the *Cephenemyia* mechanism may point the way to the realization of this almost inconceivable

we reach the *Cephenemyia* mark we shall register many lower speeds by the way. Suppose we merely increase by three fourths the U. S. Navy record of 266 miles per hour recently made by A. J. William in a Curtiss hydroplane. Even this would allow us to encircle the earth in a daylight day if we fly farther north. The distance around the earth on the 60th parallel is only 8,312 miles, the accomplishment of which would re-

quire a speed of only 226 yards per second or 462 miles per hour maintained for eighteen hours. Starting from Juneau or Dawson at 3:30 A. M., this circuit could be made via Nome, Siberian points, Petrograd, Reykjavik and Hudson Bay back to starting point by 9:30 P. M. This, a less ambitious mark than that afforded by the 40th parallel course, we may confidently expect to realize in a few more years if we apply to airplane development the results to be secured from a study of flight in flies.

It is certain that what has been attained by animals in the way of locomotion can be equalled if not exceeded by machines. All the work-performing feats accomplished by animals rest solely, in the last analysis, on purely mechanical principles. Thus the whole matter is practically a problem in mechanics, but in those as yet unknown mechanical principles involved in the structures of *Cephenemyia*[2] and its congeners.

If the actual speed of these flies be only half the estimated, they are well worthy of investigation in the interests of mechanical flight.

[2] For details of *Cephenemyia* in North America and photographs of the flies, see *Journal of the New York Entomological Society*, XXV, pp. 98–105; and XXIII, pl. 11.

BIRD LIFE IN KAMCHATKA[1]

By AUSTIN H. CLARK
SMITHSONIAN INSTITUTION

KAMCHATKA is a place all of us have heard of, though few of us have been there. We have not been there because it is one of the most difficult places in the world to get to, there being no regular communication between it and other regions. We have heard of it because in school geographies it is commonly given as the typical peninsula. From the northeastern end of Asia it extends in the form of a pointed leaf in a southwesterly direction separating the Sea of Okhotsk from the Bering Sea and the Pacific Ocean. Beyond its southern tip, called Cape Lopatka, a chain of islands called the Kurils runs southwestward to Japan.

Kamchatka has a central backbone of mountains, some of them over fifteen thousand feet in height. Among these mountains, mostly on the eastern side, there are no less than twelve active volcanoes, some of which from time to time break out into violent eruptions, and twenty-six craters.

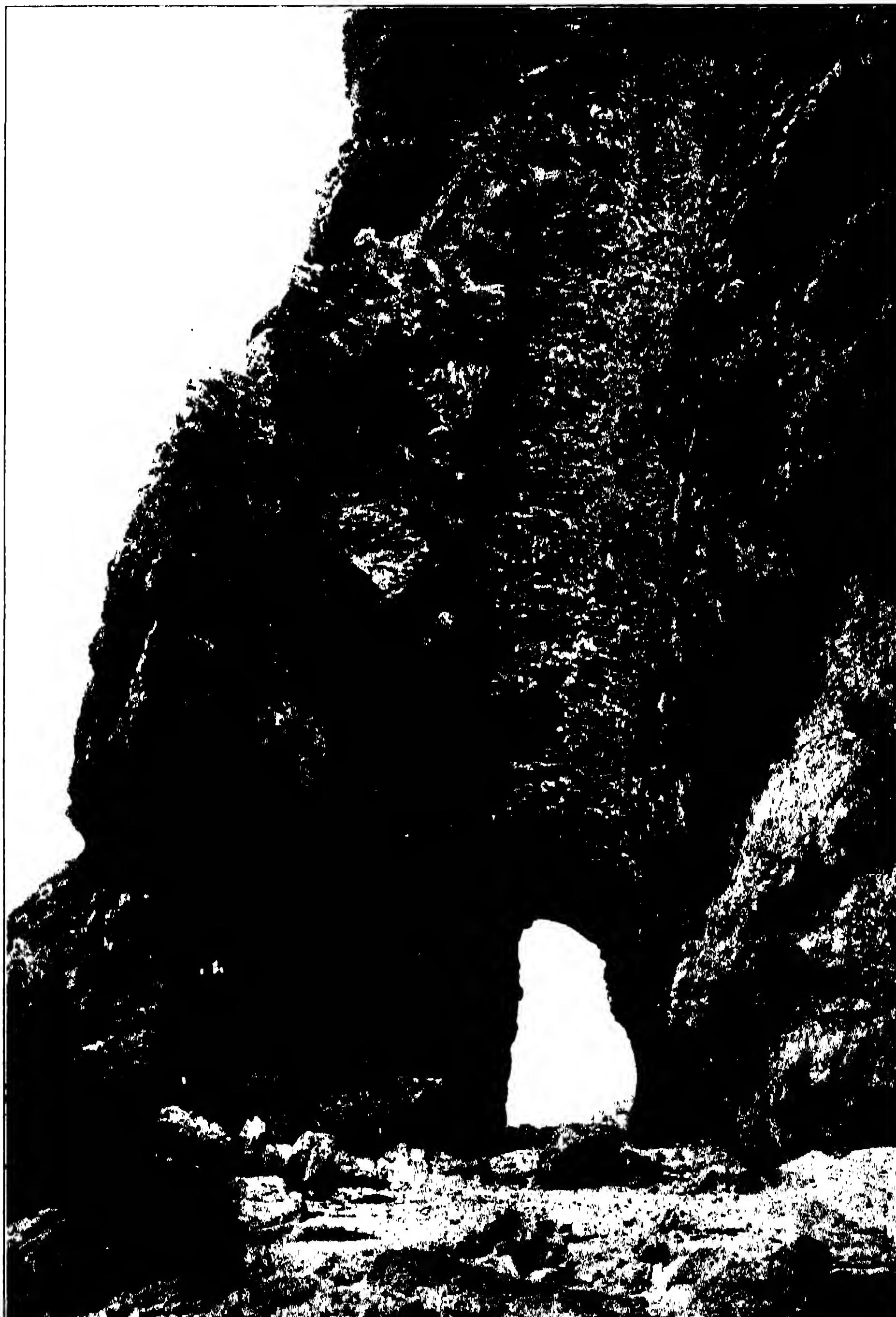
It gets very cold in winter in Kamchatka. In January the average temperature in the northern part is about 6° below 0°; at the southern end it is about 19° above; and at Petropaulski, the chief town in the southeastern portion, it is about 17° above. The western coast is much more desolate than the eastern and is very considerably colder in the winter, but the snowfall is much heavier in the east than in the west. Toward the south especially the snow often lies so thickly that the natives can not keep reindeer.

During summer the weather is very uncertain with frequent rains and fogs, but in the center of the peninsula especially there is a large amount of warmth. Vegetation, especially on the volcanic soils, is remarkably luxuriant. In the warmer valleys the grass grows nearly five feet high and may be cut three times a season. In the woods berries, mushrooms and the Martagon lily abound, the bulbs of the last being also used as food by the natives.

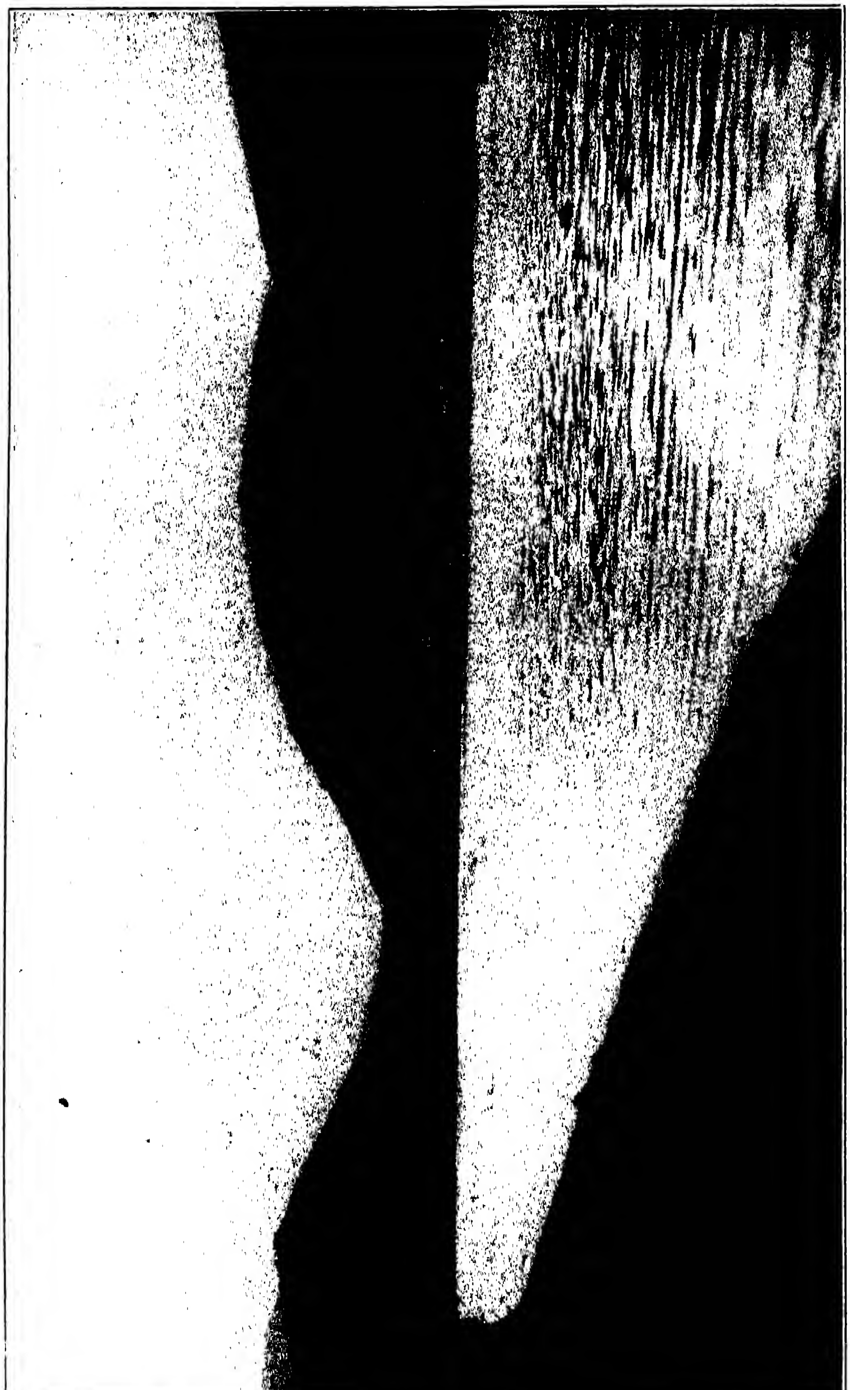
For such a large region the population of Kamchatka is very small, and there are few towns of any size. Other than Russians the people are chiefly Kamchadales. They speak a curious language, the sound of which has been compared to that of water gurgling out of a narrow mouthed jug.

One's ideas of any region are often profoundly influenced by first impressions. I reached Petropaulski from Bering Island in the Commander group after having spent nearly a month in the bleak and desolate Aleutian chain where the sun is almost never seen, where drizzling rain or fog or sleet is the usual thing in summer, where the higher land is always more or less snow covered, and where no trees of any kind can grow, though in the warmer places in the lowlands there is sometimes found a wealth of flowers which is quite surprising. In steaming up Avacha Bay toward Petropaulski in calm and perfect summer weather the sight of the pretty wooded hills about the town, the broad meadows, and the great snow-covered mountains in the distance, combined with the songs of hundreds of birds all about, produced a very deep impression and at the time I

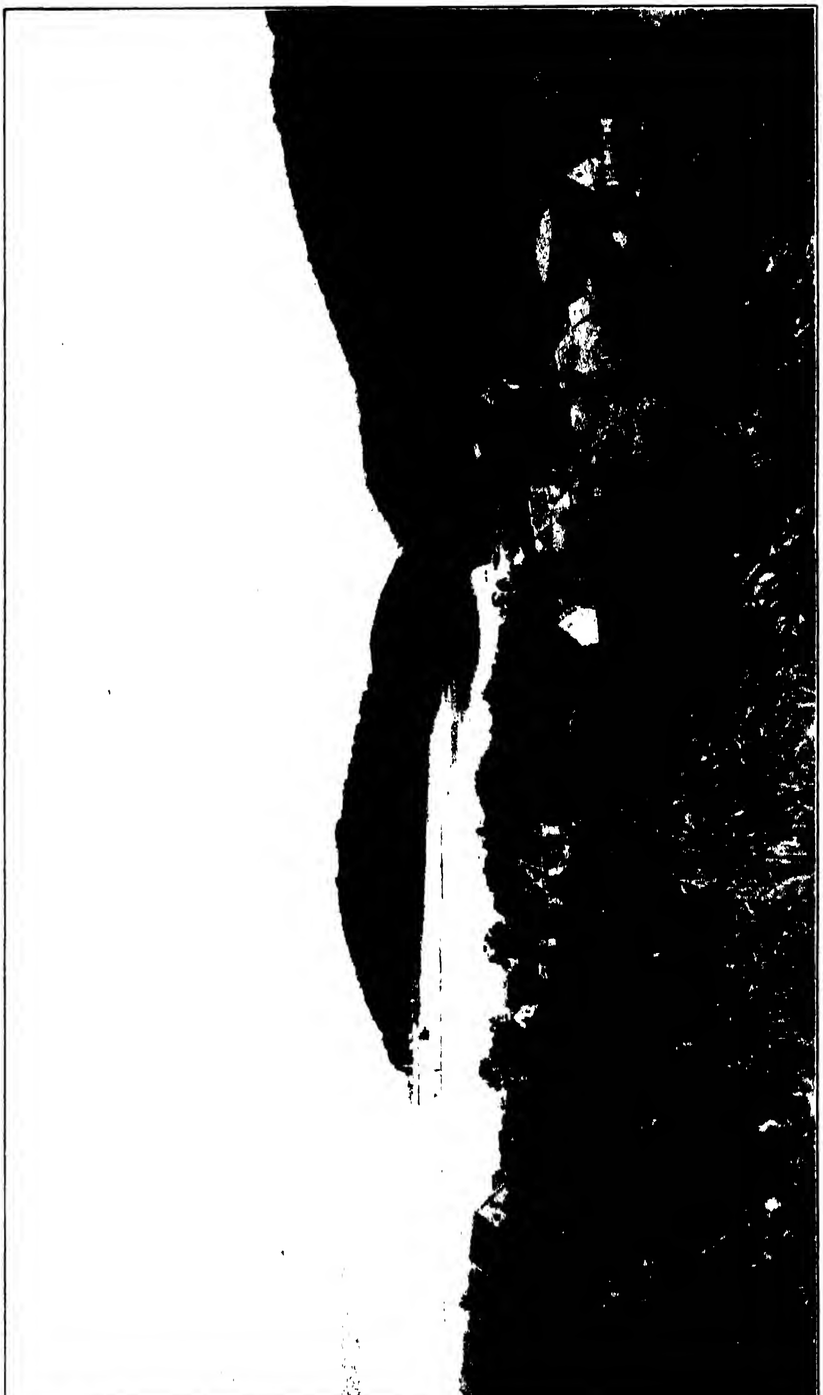
[1] One of a series of Radio Nature Talks from the National Zoological Park, Smithsonian Institution, broadcasted from Station WRC, Washington, January 23, 1926. The photographs of Petropavlovsk are furnished by the courtesy of Dr. Leonhard Stejneger; the others by the courtesy of the Bureau of Fisheries.



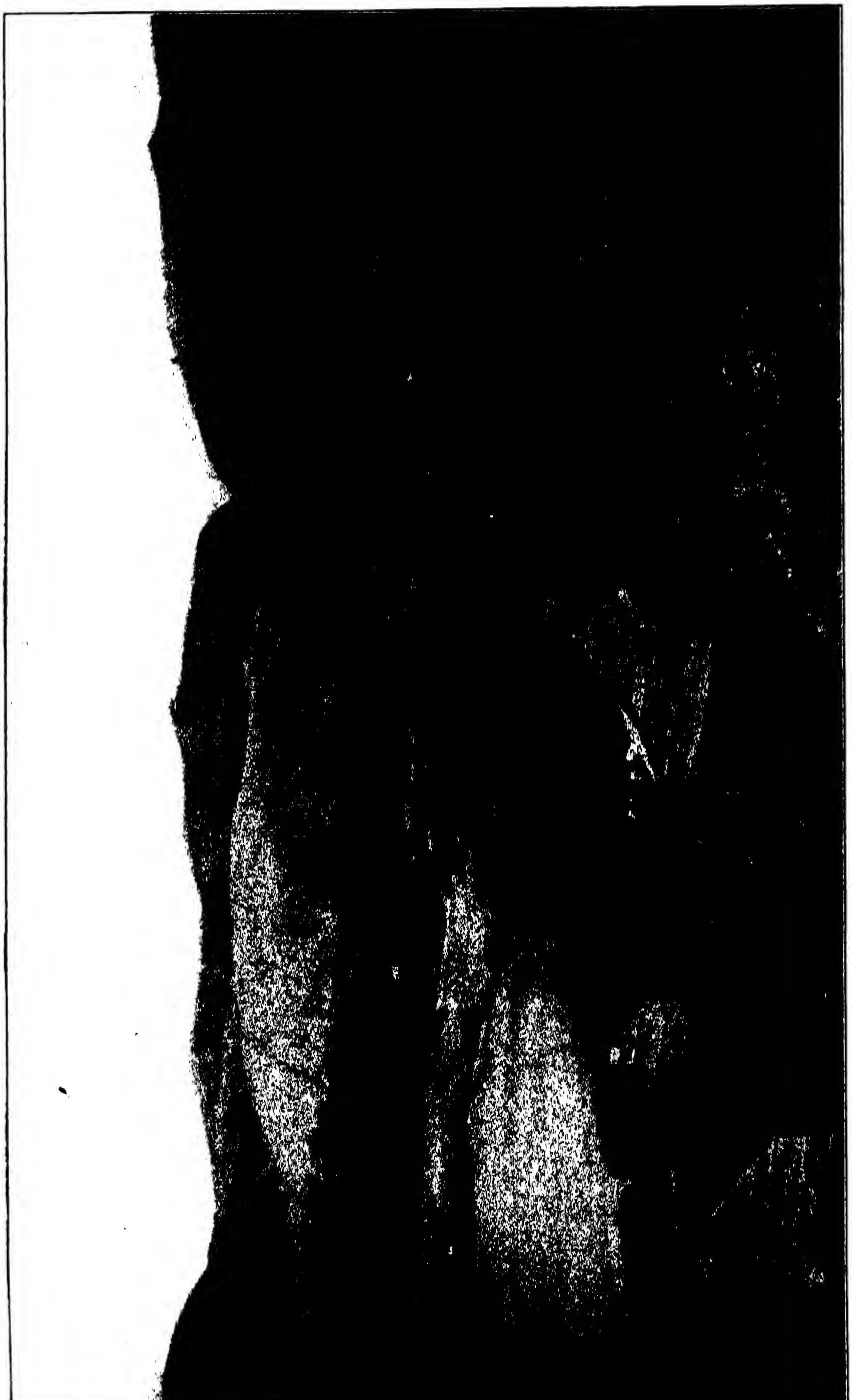
A natural arch in the cliff on Amaknak Island, near Unalaska village (Iliuliuk).
Taken in 1890.



PETROPAVLOVSK, KAMCHATKA, FROM THE OUTER HARBOR. TAKEN IN 1897.



The Inner and Outer Harbor at Petropavlovsk, Kamchatka, from a hill behind the town; just beyond the middle of the sand-spit can be seen the monument commemorating the local victory of the Russian fleet in the Crimean war. Taken in 1897.



THE VILLAGE AT ATKA. TAKEN IN 1892.

thought there could not anywhere exist a more charming spot than this little town in farthest Siberia. The weather during my stay was perfect, warm and summerlike, with the sun shining almost all the time.

The first bird in Kamchatka to attract attention is the Siberian ruby-throat, sometimes called the Kamchatkan nightingale. This little bird is not remarkable for its coloration, for it is rather plain, nor for its ubiquitousness, for it is quite retiring; but it is remarkable for its most exquisite song. It is abundant about Petropaulski and sings all day long from sunrise to sunset, its song being the most characteristic bird note of the region. It lives especially on hillsides grown up to bushes and in bushy patches in the meadows, keeping usually on or near the ground, and it is very adept at slinking away through the undergrowth if it is alarmed. The song is usually given from some little elevation, as the top of a bush or the lower limbs of a small tree, but often from near the ground.

Next in importance as a songster, and much more often seen, is the Kamchatkan house-finch, which in general habits and song resembles our common purple finch. This bird frequents the hillsides, but keeps to the more open places, the higher branches of the small trees and the tops of the bushes. It is vivacious and restless, never stopping long in any one place.

The last of the really characteristic songsters occurring about the outskirts of the town is the handsome yellow-breasted bunting which is very common, but scarcely equal vocally to the two preceding. It is much like the house-finch in its habits, but it is less active and less familiar. A similar bunting with a white breast is not uncommon, but I did not succeed in identifying its song.

A near relative of the European skylark is common in the grassy meadows, and its fine song is characteristic of the more level country behind Petropaulski.

A very characteristic bird note of this region is the loud clear call of the eastern cuckoo, quite like that of the European bird, though entirely unlike that of any bird we have with us. The call of the cuckoo was heard at all times, and the birds were frequently seen coursing swiftly around the hillsides or the clumps of bushes in the meadows, from their color and their actions looking much like hawks.

One of the most curious of the small birds of this region is the slate-colored bunting. It lives in the densest alder thickets along the banks of the small streams, keeping on or near the ground. In its habits it reminds you of our white-throated or white-crowned sparrows.

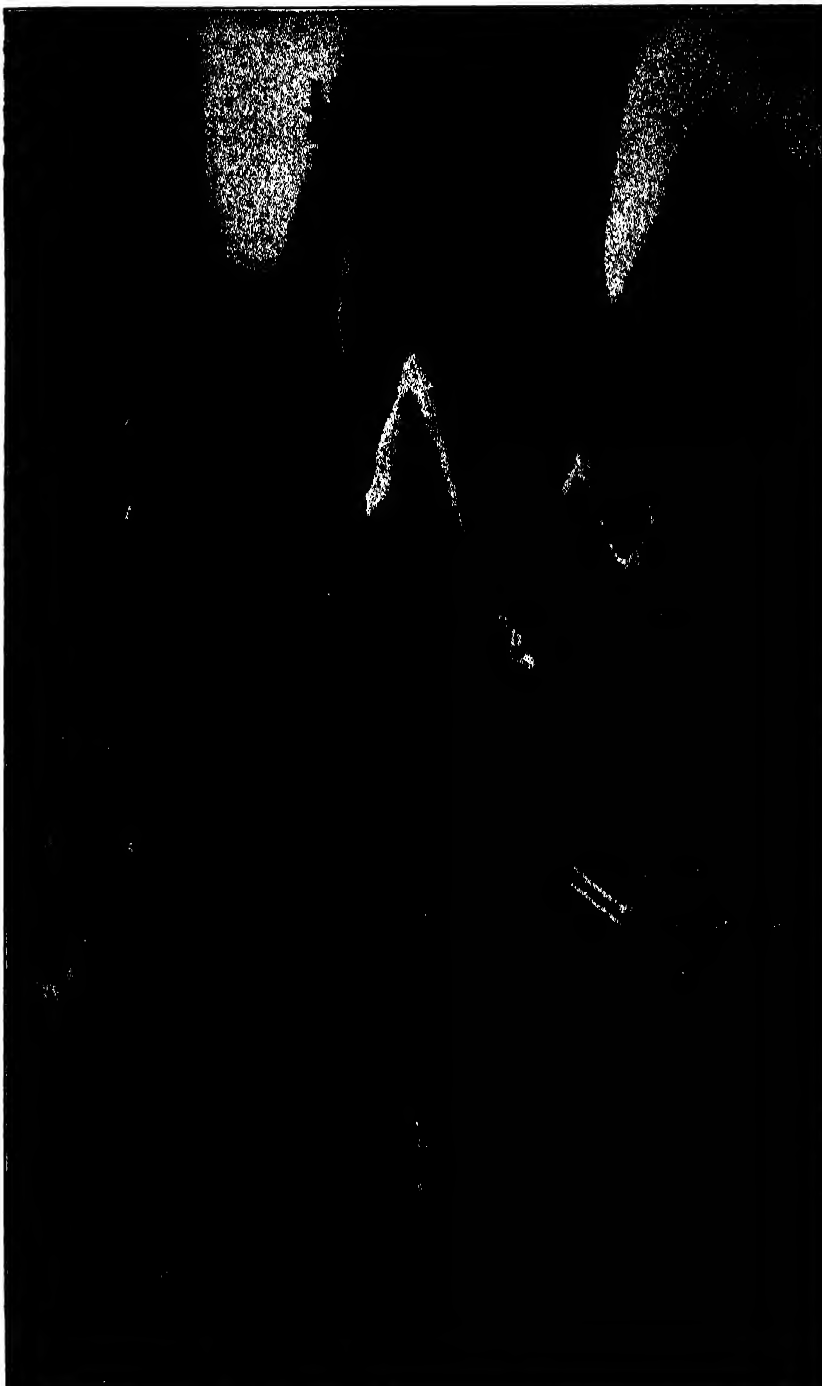
The most conspicuous of the local birds, and one of the handsomest as well, is the Kamchatkan magpie. The magpie is common everywhere, although it is very wary and usually manages to keep well out of gunshot.

Wagtails of two sorts are common. The black-backed Kamchatkan wagtail frequents the seashore, especially the rocky beaches, while the Kamchatkan yellow wagtail is very common in the grassy lowlands.

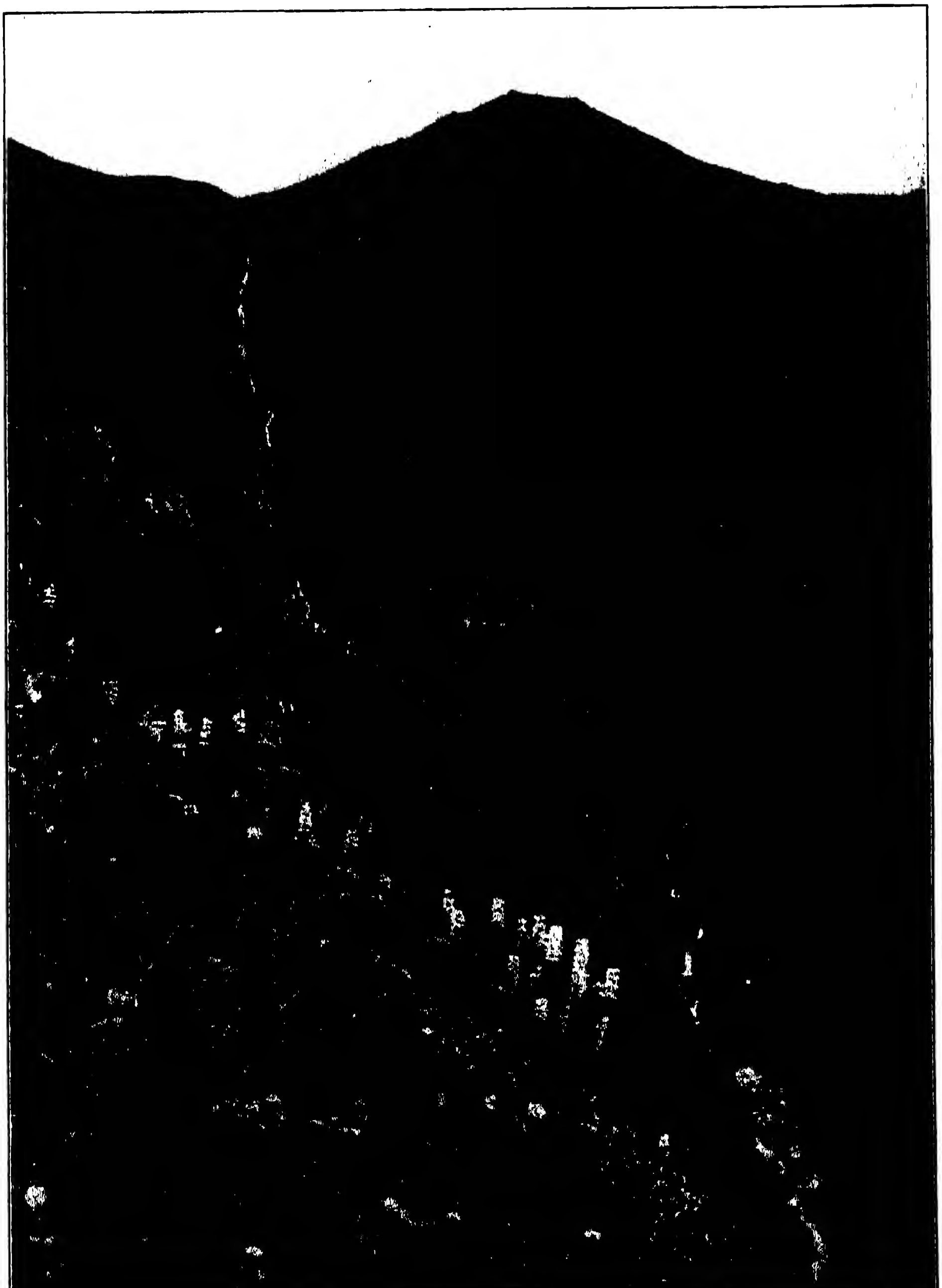
Whenever I went near any groves of tall trees I was sure to hear a continuous hooting somewhat resembling that of the barred owl; but when I tried to get close enough to find out what was doing the hooting, it would invariably cease long before I was within range, to be immediately resumed from some distant grove. I suppose the bird was the Siberian hawk owl which is the only owl known from the country.

About the taller trees also the eastern tree pipit was common, its song and actions instantly calling to mind our common ovenbird.

Of the larger birds the eastern carrion crow is numerous and was breeding at the time of my visit. I found a number of nests, none of them, however, accessible. The raven is not uncommon, though I saw but one or two. The osprey is very common, and the large Kamchatkan sea eagle, resembling the bald eagle



THE VILLAGE AT ATTU, ALEUTIAN ISLANDS. THE WHALEBOAT ON THE BEACH IS FROM THE "ALBATROSS." TAKEN IN 1894.



WILD FLOWERS COVERING THE HILLS AT UNALASKA. THE WELL-KNOWN BOTANIST, MR. PAUL C. STANDLEY, SAYS OF THIS PICTURE "THE MOST CONSPICUOUS FLOWER IS THE LUPINE, *Lupinus nootkatensis unalaskensis*; THERE ARE SEVERAL CONSPICUOUS PLANTS OF *Geranium erianthum* AND OF A DAISY WHICH, I SUPPOSE, IS *Erigeron peregrinus*; THE VERY LARGE COMPOUND LEAVES ARE THOSE OF *Heracleum lanatum*." TAKEN IN 1888–89.

SHISHALDIN VOLCANO, UNIMAK ISLAND, FROM BERING SEA. TAKEN IN 1890.

but with white shoulders and a pointed tail, is frequently seen.

Among the water birds the large slaty-backed gull is the most abundant, occurring everywhere about the seacoast, while the blackheaded gull is very common about the large pond behind the town, and is occasionally seen about the inner harbor.

Along the Kamchatkan coast I missed the immense number of sea birds, especially the puffins, murres and small auks of various kinds, which swarm about the Aleutian Islands. In fact sea birds seemed to be quite uncommon. The tufted puffin, a grotesque chubby little bird, which is perhaps the most characteristic sea bird of the Bering Sea, was fairly common in Avacha Bay, and I saw it frequently down the coast to Cape Lopatka and on the Okhotsk Sea side of Kamchatka as far north as I went. But its numbers could not be compared to those about the western Aleutian or the Commander Islands.

On May 28 we visited the Bogosloff Islands, a group of small volcanic islands north of Atka, one of which was first reported in 1796, a second in 1884, while we were so fortunate as to be the first to discover the third. When we sighted this third island steam was roaring out from fissures and cracks all over it, forming a huge steam cloud which, driven by a strong wind, passed to and over the horizon. In spite of the constant roaring, which could be heard for some miles, the adjacent Castle Island, which was the first to be reported, swarmed with birds. With a glass countless myriads of sea birds could be seen flying about along the shores, over the sea, and to a considerable height over the land. I have never anywhere else seen any approach to the enormous numbers of sea birds which swarmed about this singularly desolate island. We did not dare to go in very near, so I can not say just what these birds were. But on the sea about us were large numbers of tufted puffins, and even more murres, so I judged that these were the birds that chiefly made up the vast numbers seen about the land.

Preeminent among the sea birds of the Kamchatkan coast is the short-tailed albatross. It is not very common here, but I saw it both on the Pacific and on the Okhotsk Sea side of the peninsula. This particular albatross is curious in being very shy and usually keeps well away from ships; or perhaps it simply does not pay any attention to them. You see one in the distance, its white underside showing conspicuously against the gloomy sea, and then in a few minutes it is gone again over the horizon. This is in marked contrast to the habits of the dark brown black-footed albatross so common off our western coast and south of the Aleutian Islands. This bird displays a great interest in ships and will follow them for days, often in numbers. One day about twenty miles southeast of Unalaska I counted twenty-two of them behind the ship where they had collected to examine a large piece of meat that I was trailing in the water. The black-footed albatross, unlike the short-tailed albatross, will not enter the Bering or Okhotsk seas, keeping always to the open Pacific.

Desolate and lonely is the southwest Kamchatkan coast, a barren and uninteresting land, with strange inhabitants singularly forlorn in aspect and loath to speak to strangers in the little Russian that they know. But it was here that we formed the first home contacts we had had for several months, for we most unexpectedly came across two barkentines, the *City of Papeété* and the *S. N. Castle*, both from San Francisco, anchored on the cod banks. These boats were both besieged by scores of fulmar petrels on the watch for scraps.

This formed our last impression of Kamchatka. After a brief examination of the cod banks and the return of our surgeon, whose services were required by both ships to attend some injured men, we turned southwestward and left Kamchatka for the more congenial atmosphere of Japan.

ARCHEOLOGY IN THE SOUTHERN STATES [1]

By HENRY B. COLLINS, JR.

U. S. NATIONAL MUSEUM

In many localities of the Mississippi Valley and eastward there may be seen to-day great artificial mounds of earth, piled up by human hands, some of them built many centuries before the coming of the white man. Some of these earthworks are of such magnitude that they are familiar to archeologists everywhere, while many of the smaller ones may not be known beyond their immediate neighborhood. In the south these mounds are the only lasting monuments that have been left behind by the prehistoric inhabitants. They are thus usually the center of interest in any consideration of the archeological problems of this area.

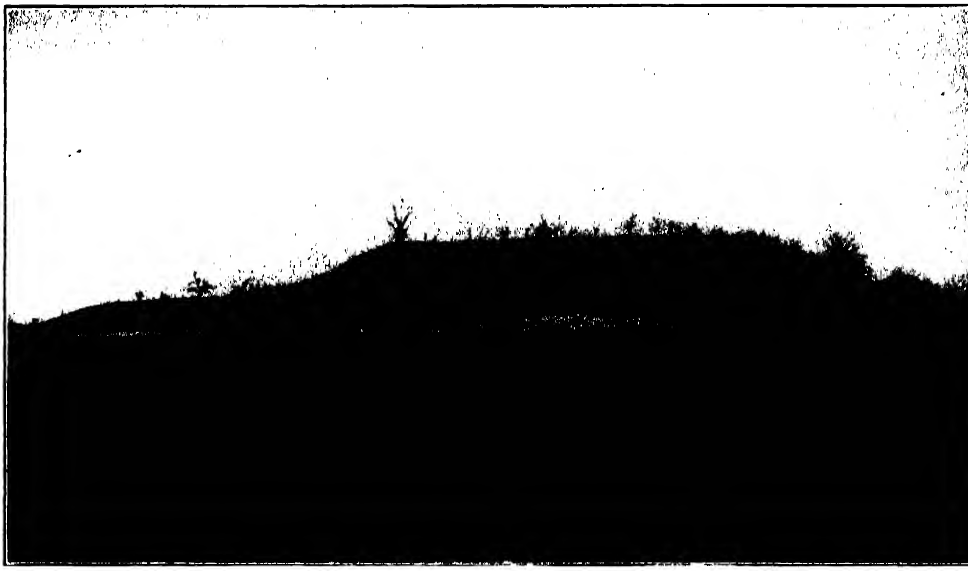
For many years the mounds were a favorite topic of discussion among antiquarians, and various fanciful theories were advanced to account for their origin. The prevailing opinion for a long time was that these mounds were the work of an ancient and mysterious race, entirely distinct from the American Indian. Another explanation was that they had been built by Toltecs or Aztecs, who, after living for some time in the region, were driven southward into Mexico.

Such romantic theories as these held sway for a number of years, and it was not until near the close of the past century that they were finally put at rest by the clear demonstration that most of the mounds were erected by the ancestors of the present Indians, and that some of them, in fact, were constructed by the modern tribes after they had come into contact with the whites. We know to-day that there never was a "race" of mound-builders; the building of mounds was simply a custom that was shared by a number of Indian tribes of different stocks. The most important questions that now await explanation are the origin of the custom of mound-building, the period of construction of the mounds, and the tribal affiliations of their builders.

This information must come mainly from three sources. The first and most important is the evidence furnished by the mounds themselves. While outwardly many of them present much the same appearance, excavation has shown that there are a number of distinct types, which tend to be restricted to certain areas. For instance, the effigy mounds of Wisconsin, with their characteristic animal shapes, were built up in an entirely different manner from the burial mounds of Ohio or the large pyramid-shaped mounds of the southern states. The stone weapons and implements, the pottery and the ornaments that were placed in the mounds by the builders and often the bones of the builders themselves are also found to differ considerably. It is possible, therefore, by comparative study to determine the relation of some particular group of mounds with those of other areas and with the tribes later inhabiting the region.

Secondly, we have the traditions of the modern Indians, which, while they

[1] One of the Smithsonian series of radio talks arranged by Mr. Austin H. Clark; given from Station WRC, Washington, February 11, 1926. The photographs are furnished by courtesy of the Bureau of American Ethnology, Smithsonian Institution.



CAHOKIA, FROM THE EAST, AN OUTSTANDING EXAMPLE OF THE SOUTHERN TYPE OF HABITATION MOUND. THIS MOUND, WHICH IS ABOUT 6 MILES EAST OF ST. LOUIS, MO., IS THE LARGEST PREHISTORIC EARTHWORK IN THE UNITED STATES. IT IS 100 FEET HIGH AND COVERS AN AREA OF ABOUT 16 ACRES. SURROUNDING IT AT ONE TIME WERE MORE THAN 60 OTHER MOUNDS.

can not be relied on entirely, may sometimes afford valuable clues as to their early customs and migrations.

A third source of evidence, and one which is of particular value in the south, is that furnished by the accounts of the early explorers, Spanish, French and English. The earliest and most important of these historical accounts are those left by the chroniclers of the De Soto expedition in 1540, who give numerous descriptions of the Indian villages and of the artificial mounds on which some of the houses stood.

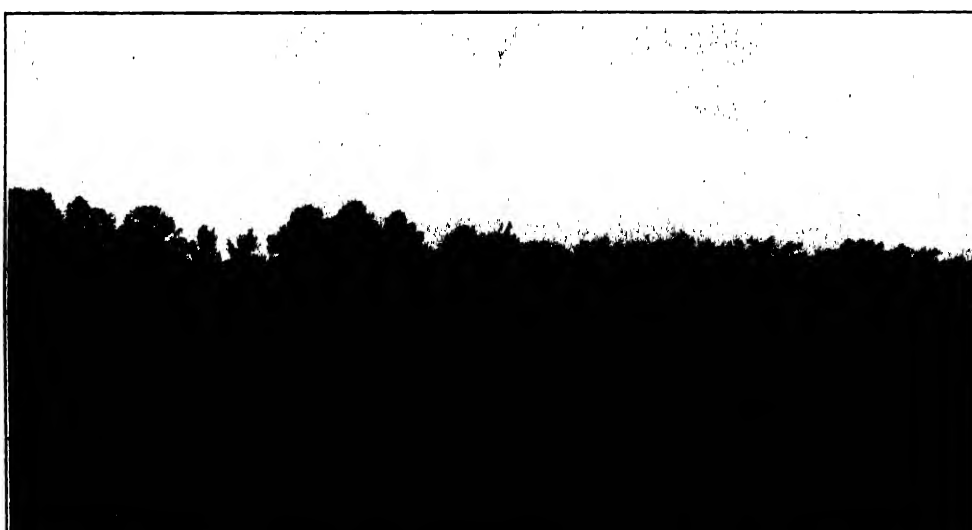
In order that we may more readily understand the conditions under which some of these earth monuments were erected, let us see what one of them reveals upon excavation. As an example I shall select a mound in southwestern Arkansas which was opened some years ago by Mr. Clarence B. Moore. This mound was roughly circular in outline, with a basal diameter of about eighty feet and a height of eleven feet. As the upper layer of soil was removed there were found nine large pits which extended down to about the base of the mound and in the bottom of each pit was a skeleton accompanied by a rich mortuary offering. Extending twelve feet into the undisturbed soil beneath the bottom of the mound was another large pit in which rested the skeleton of an aged male. With this burial there had been placed many pottery vessels and weapons and ornaments of stone and copper, while a thick black layer beneath the bones gave mute evidence of other more perishable material that had long since disappeared.

What do these facts reveal as to the identity and customs of the people who constructed the mound? First, it is very evident that the remarkable burial twelve feet beneath the base of the mound was that of a person of some prominence. The great depth of the pit,

which had to be dug laboriously with crude implements of bone and wood, together with the great number of objects deposited therein, are definite indications that the individual thus honored was a man of more than ordinary importance. Moreover, there is every reason to believe that the mound itself was erected as a memorial over this grave. The nine other burials which were made in the mound at a later date were carefully arranged in a circle above the original pit, these upper burials all apparently having been made at one time. It seems very probable, therefore, that here again we have the burial of some important personage, this time along with eight others who had been sacrificed in order that they might accompany him into the spirit world.

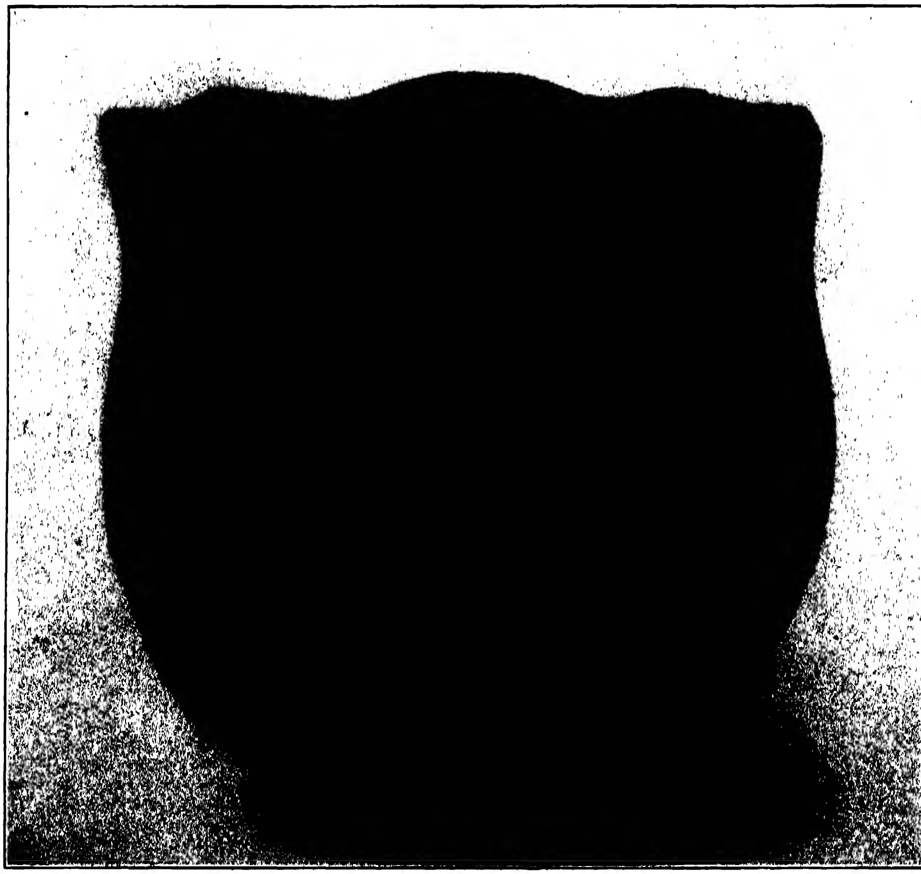
It must not be supposed that either human sacrifice or the existence of a caste system was common among American Indians. On the contrary these features have been observed in only a few instances north of Mexico. The most outstanding example, however, is presented by the Natchez, a tribe living in western Mississippi when first seen by Europeans. This is no great distance from southwestern Arkansas where the mound just described is located, and since the early movements of the Natchez seem to have been from west to east, there is a strong indication that the builders of this particular mound were a people related to the Natchez, a fact that is still further suggested by a similarity in physical type.

The burial customs of the Choctaw, a large tribe formerly living in eastern Mississippi, were different from those of the Natchez, as we know from historical accounts. When one of their number died it was the custom among the Choctaw to place the body on a scaffold or platform erected for the purpose. After remaining exposed for some months it was taken down by the so-called "bone-pickers," whose official duty it was to carefully scrape and clean the bones. These were then placed in cane hampers and deposited in the bone house, one or more of which was to be found in every



NANIH WAIYA, SACRED MOUND OF THE CHOCTAWS, IN WINSTON COUNTY, MISSISSIPPI. ACCORDING TO CHOCTAW TRADITION THE FIRST OF THEIR TRIBE CAME UP FROM THE UNDERWORLD THROUGH THIS MOUND.

STEATITE PIPES FOUND NEAR NASHVILLE, TENN.



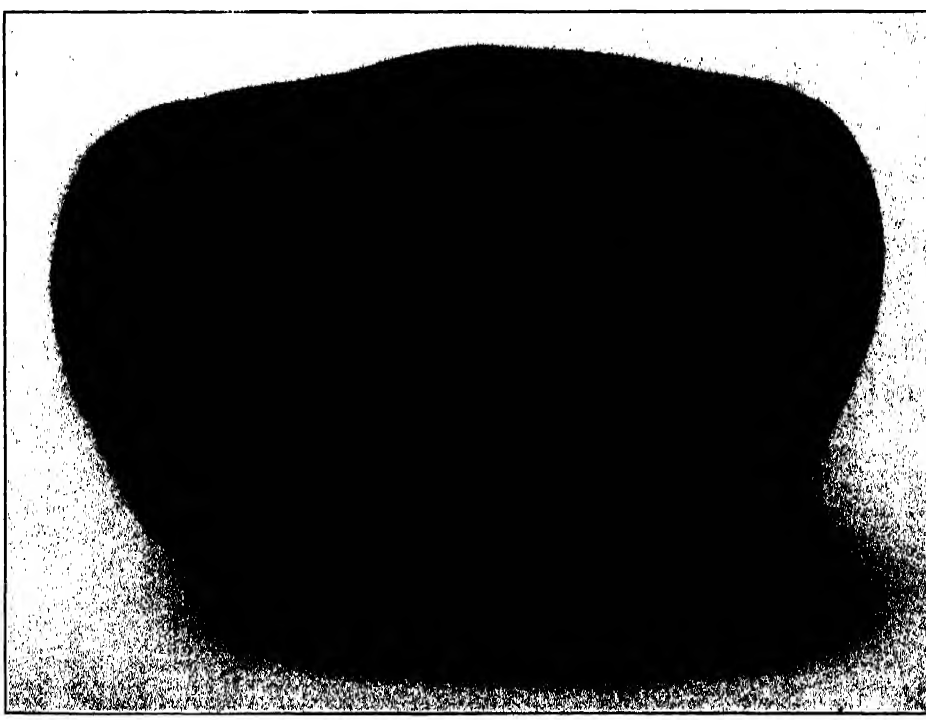
POTTERY FROM WEEDEN ISLAND, WESTERN FLORIDA.

Choctaw village. When a number of skeletons had thus accumulated they were carried some distance away from the village, placed on the ground and covered over with a small mound of earth. In this custom we have an explanation of the many groups of small burial mounds which are found throughout the territory formerly occupied by the Choctaw. Most of these mounds are less than four feet high and average about thirty feet in diameter, and the bones which they contain are usually found in a compact mass near the center.

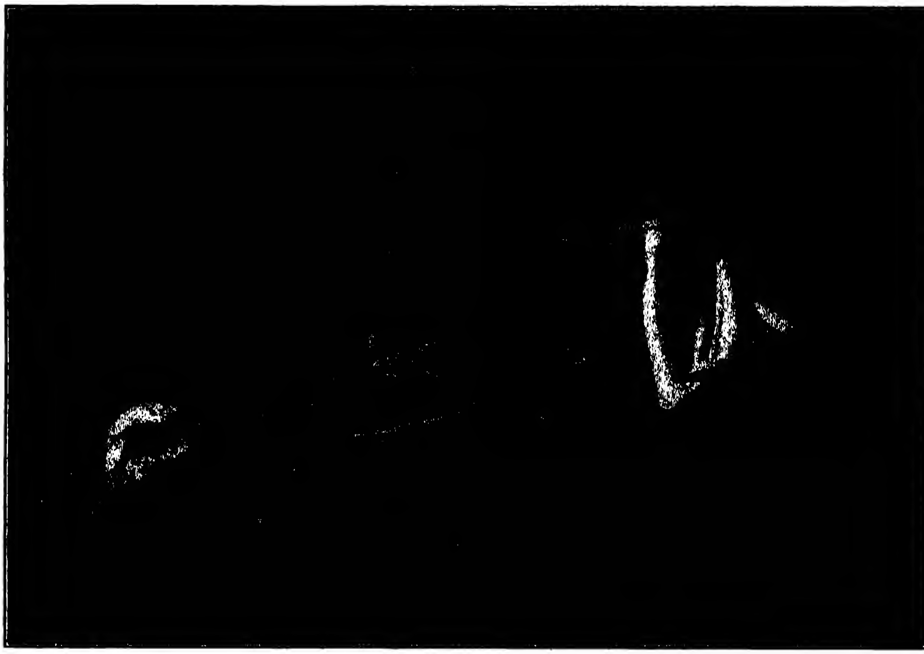
The most imposing earthworks of the southern states are not those which were erected for burial purposes, but the huge pyramid-shaped mounds, so characteristic of this area, on which were placed the temples and habitations of the chiefs. The largest of these structures in the south is the great Etowah mound in Georgia, which was probably built by the Cherokee. This famous earthwork is over sixty feet high and covers an area of no less than three acres. When we consider the manner in which this mound was erected, the laborious process of digging the earth with crude implements of flint or bone, gathering it up in small quantities in baskets or skins and slowly piling it up, load upon load, we realize

what a tremendous undertaking this must have been for a primitive people, and can not but marvel at the impelling force which drove them on to the completion of such a task. It is not in keeping with the indolent spirit which is so commonly attributed to the Indian. However, it should be borne in mind that, like other primitive peoples, the Indian was intensely religious, and willing to go to any length in order to see that his relations to the forces which controlled his universe should be observed with the dignity and rigidness that tradition demanded. The many large mounds on which their temples once stood and those erected as monuments over their dead thus afford direct evidence of the important place that religion held in the estimation of the Indian.

Slowly but steadily the mystery of the mounds is being solved—or rather, dispelled. Historical and archeological evidence now reveals with some certainty the identity of the builders of most of the mounds and other earthworks of the south. With but few exceptions they are the work of the Indian tribes which were found occupying the region in the sixteenth century. The most important of these tribes were the Timucua in Florida; the Cherokee in the Appalachian region of Georgia, Tennessee and the Carolinas; the Creeks in Georgia and Alabama; the Choctaw, Chickasaw and Natchez in Mississippi; and the Quapaw and Caddo in Arkansas and Louisiana. These tribes, together with smaller allied groups, possessed collectively perhaps the highest culture north of Mexico. Their country was rich in game, fish and wild food plants, and yet we find that these tribes practiced agriculture on a rather extensive scale. They were strictly sedentary, living in permanent villages, and their houses were well-built structures with frameworks of small logs



Another example of Weeden Island pottery.



A FLEXED SKELETON IN THE NACOOCHEE MOUND, NORTHEASTERN GEORGIA, SHOWING ORNAMENTS BURIED THEREWITH.

or poles and walls of wattle work and plastered clay. The more important towns were fortified by embankments of earth in which were set rows of stakes, while the mounds on which the temples and other principal buildings stood were no doubt used at times for purposes of defense.

The religion of most of the southern tribes was based upon sun worship, which was observed in its purest form among the Natchez. With this tribe sun worship was accompanied by a rigid caste system, under which the ruling class, or Suns, as they were called, were regarded as the direct descendants of the sky god, and exercised a most despotic power over their subjects. Among the other tribes of the south a much more democratic form of government prevailed. The chiefs had but little authority, and each village conducted its own affairs.

The mounds, as the most tangible of the Indian remains in the south, have been considered at some length. It is by no means certain, however, that the mound-building tribes were the first who occupied the region. Indeed, it might be more safely stated that they were the latest, for without doubt many of the mounds, large and small, were constructed after the coming of the whites, as is shown by the frequent finding of European objects in them, not only in the upper parts where they might be regarded as of secondary origin, but in the lower strata as well, and in some cases even beneath the mounds themselves. In addition, there is the evidence already referred to of the historic tribes using mounds as sites for certain of their buildings and erecting small mounds over the bones of their dead. Mound-building persisted, therefore, until a fairly late date.

When we seek to determine the origin of mound-building the facts all seem to point in one direction—to Mexico and Central America. In these regions there developed the highest civilizations in America, those of the Maya, Toltec and Aztec, whose intellectual and material achievements rivalled in splendor the ancient civilizations of the Old World. Here there are found great mounds of earth, similar in form and function to the large flat-topped mounds of the southern states. The mounds of the Maya, Toltec and Aztec were faced with stone, and the elaborate stone temples rising above them were of course vastly superior to the wooden structures which surmounted our own mounds. The underlying principle, however, was the same. There are other similarities that should be noted. Copper plates and ornaments of shell and stone found in the mounds bear decorations of a distinctly Mexican type. This resemblance is also observed in the stone pipes or idols and in the decorative designs on pottery.

Certain customs and various features of the religion and social organization of the southern tribes seem also to have been influenced by the higher cultures of Mexico and Central America. These facts are in no way startling or unexpected. On the contrary, it would be very strange if the influence of such high cultures as those of the Maya and Aztec should not have left some impression on surrounding peoples. While there seems to be but little doubt that such an influence was exerted, the process by which it was passed on is still obscure. It is possible that certain elements of Mexican or Central American culture were carried northward by means of a direct migration of tribes at an early date. On the other hand, the similarities in the culture of the two regions may merely indicate that the mound-building tribes of our southern states borrowed rather heavily from the more advanced tribes further south.

The problem of the origin and spread of any particular American culture leads sooner or later to the question of man's antiquity in America. On this point it can be stated that up to the present time there has appeared no clear evidence that would indicate the presence of man in either North or South America until after the last great ice invasion.

The American Indian is basically of Mongolian stock, and since emigrating from his Asiatic home has changed very little in physical type. The time of his arrival on this continent is highly problematical. While from a geological standpoint it was comparatively recent, it may well have been as much as ten thousand years ago. From that remote day until near the close of the fifteenth century A.D. the American Indian was removed from contact with the rest of the world. Thrown on his own resources, he developed his own social patterns, which, with his spread over the two continents, became more numerous and complex. America, in this respect, is an ideal laboratory in which to study the development of civilization and the rôle played by the diffusion of cultural elements from one people to another.

The region which we have been considering to-night occupies a strategic position, both geographically and culturally, in this larger scheme. Situated along the Gulf Coast, these southern tribes would be among the first to be affected by the more highly developed civilizations to the south. They were in a position to receive, absorb and pass on in diluted form the borrowed elements from these sources, and that, apparently, is what did happen. The archeology of this region, therefore, has more than a local significance. It forms, in fact, a most important link in the chain of accumulating evidence bearing on the problems of the origin and development of aboriginal culture in America.

SEXUAL REPRODUCTION IN WATER SILK

By Professor FRANCIS E. LLOYD

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THROUGHOUT the realm of living things, the essential act of sexual reproduction takes place as a general rule when an exceedingly small male cell, the spermatozoid, unites with a relatively large one, the ovum or egg-cell. There are a number of forms, however, in which the sexual elements (gametes) are practically equal in size, and of these a fewer number in which the gametes may be seen with relative ease, and, because of equality of size, the behavior of each specifically studied.

There are two groups of plants of which this is true, the zygomycetes, of which the black moulds (Mucorineae) are well-known examples, and those green organisms, the conjugates, of which it may be especially said that they are equally yoked together. The plant which affords the subject of this account is a member of the latter group. It is so very well known, superficially at least to every one who has studied in a botanical laboratory, that to describe it seems almost superfluous. It is as necessary a type for the botanist as the frog is to the zoologist. Both are found growing and breeding in the same sort of places.

This plant, the "water-silk," "mermaids' tresses," known also by the less poetic and still less truly descriptive names "pond-scum" and "frog-spit," bears a scientific name both euphonious and graphic, *Spirogyra*, so much so that we may overlook any etymological faultiness. This plant more than any other, in the hands of the great plant physiologists Pfeffer and De Vries, led them to make the discoveries in osmosis which lie at the foundations of that now vast and intricate field of knowledge, physical chemistry. Its importance in relation to human knowledge therefore, no less than to the more circumscribed field of botany, entitles it to more than passing notice.

In the latter field it has had an important share in supplying material for important observations on sexuality from which our modern knowledge of this property has been derived. O. F. Mueller (1779), Vaucher (1805), De Bary (1858), Klebs, Pringsheim, Strasburger, Chmielewski and Hassal are among the numerous company of those who have cogitated on the meaning of the facts supplied by watching the behavior of this lowly organism. The appearance within the last very few years of lengthy and critical researches by Tröndle, Hemleben and Czurda shows that interest in it is still sustained. A full bibliography would include well toward one hundred names of students in Europe and America who have, in some way or other, studied *Spirogyra* critically, and most of them have thought on the problem of its sexual processes and properties.

What like, then, is this creature which has commanded the attention of the best thinkers in botanical science? And how is the process of sexual reproduction accomplished? Answers to these questions are presently attempted, always with the remembrance that there is more to know.

Spirogyra is a thread-like green water plant growing submersed or at times

floating at the surface, appearing in a mass as a uniform delicate green cloud. When lifted from the water it strings out like a lock of finest silky hair, whence one of its names. To the touch it feels smooth and mucilaginous, and it slips through the fingers with ease. If one places a mass of the plant in an aquarium, in a few hours it begins to grow upward, the filaments twining about each other, forming beautiful green curly locks reaching up to the light (fig. 1b, c). It may also grow about a support—is in fact a twining plant.

Examined under magnification, the separate threads, which are entirely without branching, are seen to be composed of a series of articles (cells) each like the other and having a definite structure. According to Transeau there are over one hundred species, differing in the minutiae of this structure, and in size; that is, in diameter, for they are all long and relatively most exceedingly slender. By measurement the diameter may be as little as one one hundredth of a millimeter (*Spirogyra tenuissima*) or twenty times that (*S. maxima megaspora*).[1] In figures 1a and 2 may be seen four different kinds, the smallest of which measures 26 microns (0.026 mm.), the largest 150 microns (0.15 mm.). The different figures are not at the same magnification, but it will be noted that with increase in size there is an increase in the coarseness of detail, indicating that the internal structures vary in respect of the size and character of the building stones, the architecture being the same.

Looking at the plant under the microscope it appears to be merely cylindrical, both ends, if seen, being alike. This, however, is only apparently true, since it really has an up-and-down structure or polarity. This is seen in young plants as they germinate from the spore. In such there is a basal end, which may become anchored to a convenient surface, and a top end which, by repeated growth and repeated cell-division, elongates into the filament. With much added length, it breaks away by accident or disease and the filament then is free. The upper end of a filament may

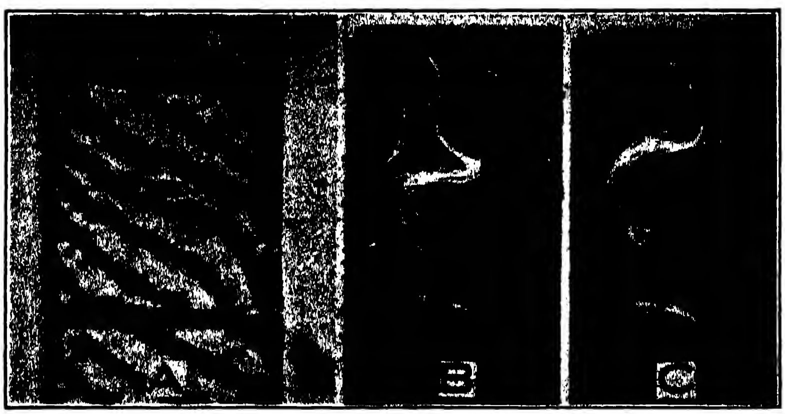

FIGURE 1.A. PART OF A FILAMENT OF *Spirogyra* TO SHOW THE SPIRAL PIGMENT BODY (CHLOROPLAST) AND THE NUCLEUS SUSPENDED BY THREADS OF PROTOPLASM. B. AND C. SUCCESSIVE PORTRAITS 2½ HOURS APART OF A CLUMP OF *Spirogyra* IN AN AQUARIUM, TO SHOW THE TWINING MOVEMENTS.

[1] Data transmitted by the courtesy of Professor Transeau.

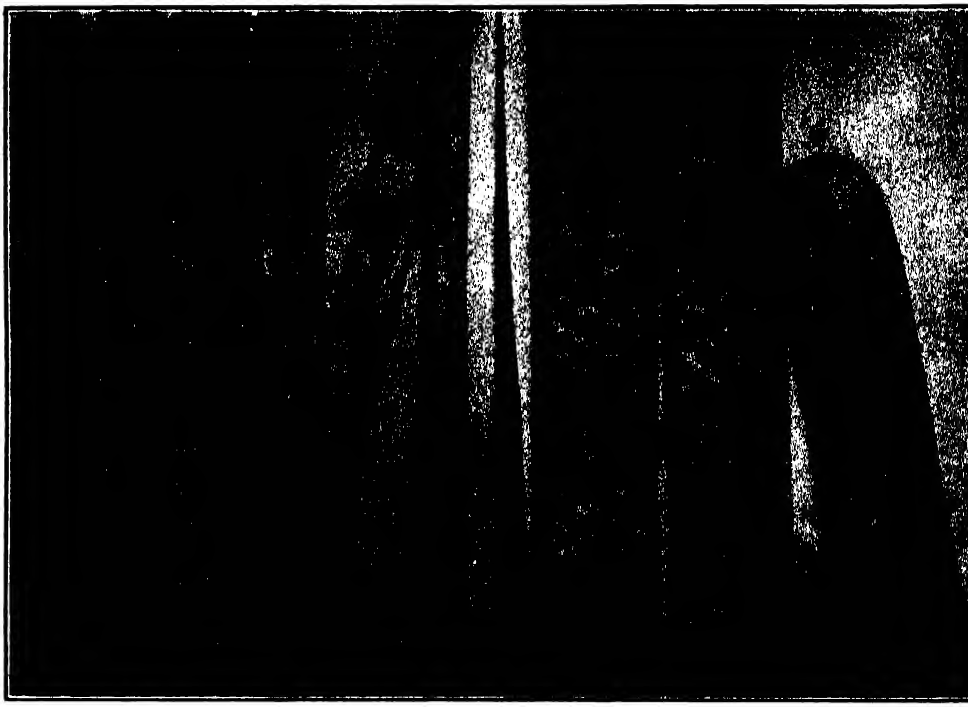

FIGURE 2. FOUR DIFFERENT SPECIES OF SPIROGYRA.

sometimes be found (fig. 2), though we may not always be quite sure that we are not looking at an end secondarily formed after a break in the thread has occurred. The filaments have the ability on occasion of sending out rootlike processes (haptera) by which they anchor and this seems to occur most frequently when short pieces of the plant lie at the bottom of their watery habitat or of an aquarium (figure 3e). When the favorable time of spring has come, these fragments together with the sporelings grow apace and the resulting myriads of individuals compose the green cloudy masses seen in quiet ponds.

In order to approach the matter to which we have addressed ourselves, we must now examine more closely the cell. Except in superficial details, all the cells are alike. On examining figure 2 a conspicuous feature is noticeable, namely, that each cell is traversed by one or more left-handed spiral bands which may be steeply inclined to the axis or less so, this varying even in the same individual. These (the chloroplasts) in life are a clear, grass green, and contain the characteristic green pigment chlorophyll, a fluorescent substance, and, when the cell is suitably illuminated, cause the chloroplasts to appear deep red. Thus seen, the rest of the cell is invisible and one sees only the brightly shining red spirals. The band is folded longitudinally, so that in transverse section it appears as a shallow V. It can be seen by the figures also that the steepness of the spirals varies with the species and is greater in the middle of the cell than elsewhere. This will be explained shortly.

Choosing a species of *Spirogyra* in which only one chloroplast occurs, for

the sake of simplicity, we examine a single cell to acquaint ourselves with its structure, and for assistance turn to the accompanying diagram (figure 4). We distinguish first, on the outside, a firm, tubular shell, a membrane of cellulose which is continuous from one cell to another. Within this is a series of other cellulose shells each proper to a single cell and forming a closed cylinder. The inner surface of this wall is clothed by a layer of the living material—this probably penetrates also throughout the cell-wall—which I estimate to be about one micron thick or less in the small species shown in figure 3. It is so transparent and apparently structureless that its outline, when in normal position, evades the vision (figure 5a). In it minute granules in varying numbers may be seen, moving more or less steadily in one direction or another. These, like leaves floating on a quiet stream, indicate the direction of flow of currents in the protoplasm. The visual demonstration of this delicate layer of protoplasm may be easily made by causing it to recede from the cell wall by bathing the cell with a 10 per cent. sugar solution. The protoplasmic sac may then be seen lying free in the cavity of the cell wall (figure 5b).

The whole relatively vast interior of the cell is occupied by the sap: water with sugars, salts, tannin and doubtless other substances in solution, in quantity approximately equal *in toto* to the amount of about 10 per cent. if it were all sugar and with colloidal material in suspension, appearing milky with the dark-field illuminator. Lying in this thin layer of protoplasm which bulges out to accommodate it is the chloroplast.

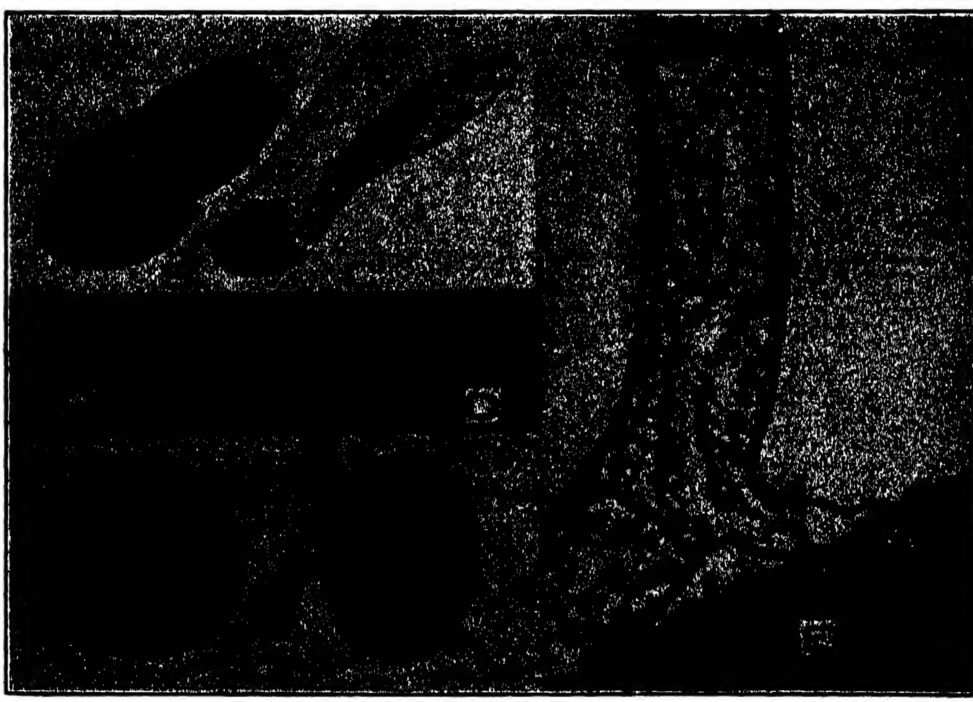

FIGURE 3. A–D. EARLY STAGES IN THE DEVELOPMENT OF A SPIROGYRA PLANT FROM THE SPORE. A. TWO SPORES IN DIFFERENT POSITIONS; THAT ON THE RIGHT HAS RUPTURED THE SPORE CASE, THE SPLIT TO BE SEEN AT THE UPPER PART OF THE LIMB. B. YOUNG ONE-CELLED STAGE. C. LATE ONE-CELLED STAGE AND D. TWO-CELLED STAGE. E. FRAGMENT OF A FILAMENT WHICH HAS ATTACHED ITSELF BY A ROOTLET.

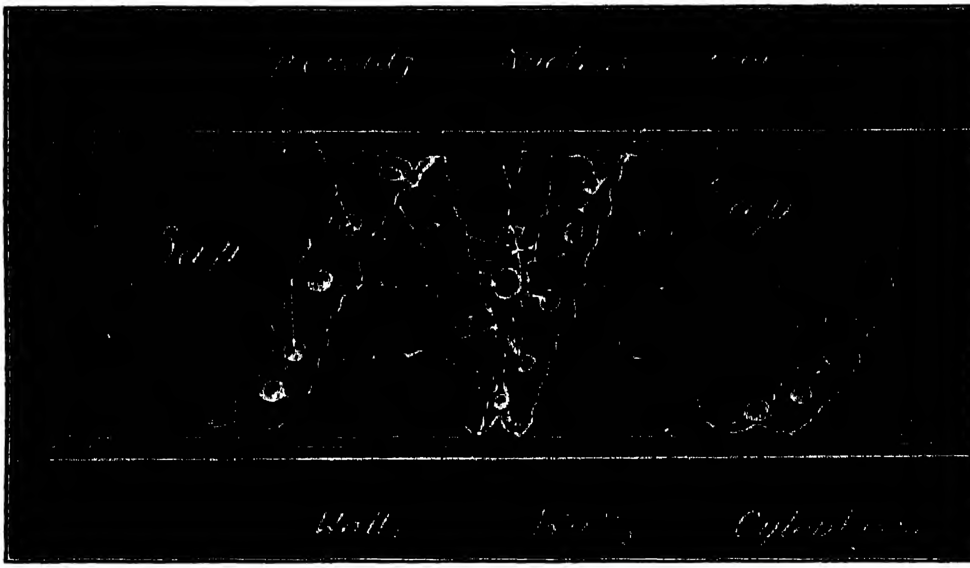

FIGURE 4. DIAGRAM OF A CELL OF *Spirogyra* DESIGNED TO INDICATE THE IMPORTANT FEATURES OF STRUCTURE. COMPARE WITH FIGURES 1 AND 5.

From this spiral bulging ridge—and sometimes from other points—delicate threads of protoplasm slightly displacing the chloroplasts extend radially toward a lenticular body, the nucleus, occupying the center of the cell. Surrounding the nucleus is a thin layer of protoplasm, so that the chloroplast and nucleus lie in and are fully covered by it.

It will be seen that the great bulk of the cell is water. This is held in place by the osmotic attraction of the substances in solution in the sap from which they can not escape because they can not pass through the thin layer of protoplasm lining the cellulose wall, so long as the cell is living. So much for the structure of the cell.

When sexual reproduction takes place two neighboring cells in a filament or two cells in neighboring filaments unite to form a single cell, the zygote, the total volume of which is 25 to 30 per cent. of the total of the two original cells. It normally contains the whole of both gametes, less only the water of the sap and possibly some solutes. Clothed w a triplex covering (figure 9h) it passes a lengthy period in a resting condition; it is this which produces in spring the sporeling (figure 3a–d). We now examine in detail the behavior of the gametes in preparing for sexual union, here called conjugation.

First when two neighboring cells conjugate. The first evidence consists in the gradual outgrowth of the side wall on each side of the transverse partition separating the gametes (figure 6). At length (24 hours or so) there has formed a curved tube from one cell of the gamete to the other, but they are still separated by a diaphragm, of cellulose of course. Before the living material of the gametes can come into contact, this diaphragm must disappear. This is brought about by digestion, speaking physiologically, by hydrolysis, as the chemist would say. The progress of the change which leads to dissolution may

be watched. First the membrane swells and becomes lax, so that it hangs like a translucent drapery between the gametes (figure 6d). Varying pressure of one gamete on the other causes the diaphragm to bulge now one way and now the other till it is finally perforated, and the gametes come into contact, when, if conditions are favorable, they fuse (figure 7a). Of these conditions, that of surface tension appears very important, just as, in an emulsion of oil in water, the oil drops will run together if water alone is used, but will not do so if something of the nature of a soap is introduced, a soap solution having a lower surface tension than water. That this condition is a real one in the case we are considering, it need only be pointed out that the gametes may be crowded into close intimacy without fusing, each forming a parthenospore, that is, a spore without sexual union (figure 6e).

The region of initial fusion is small (figure 7a) but rapidly the softened wall is broken down by the pressure of the stream of protoplasm as it flows over to join the female. Since the female occupies the whole of the cavity formed by the cell-wall, and since the male occupies the whole of his at first, the question may well be asked what happens to two bodies to enable them to condense and in consequence to occupy only one third to one fourth of their original volume. This question is seventy-five years old at least, De Bary being the first to have pondered the matter. He thought that the gametes contract by the excretion of water, or an extremely dilute watery solution. So far he was right, but he had nothing to say about how this is accomplished beyond saying that the contraction of the protoplasm is like that which occurs when the cells are bathed with a solution of sugar of higher concentration than that of the sap, and this did not help much. Later it was thought there was secreted by the protoplasm a sort of mucilage or jelly-like substance which had the effect of crowding it into less space; but the author of this conception,

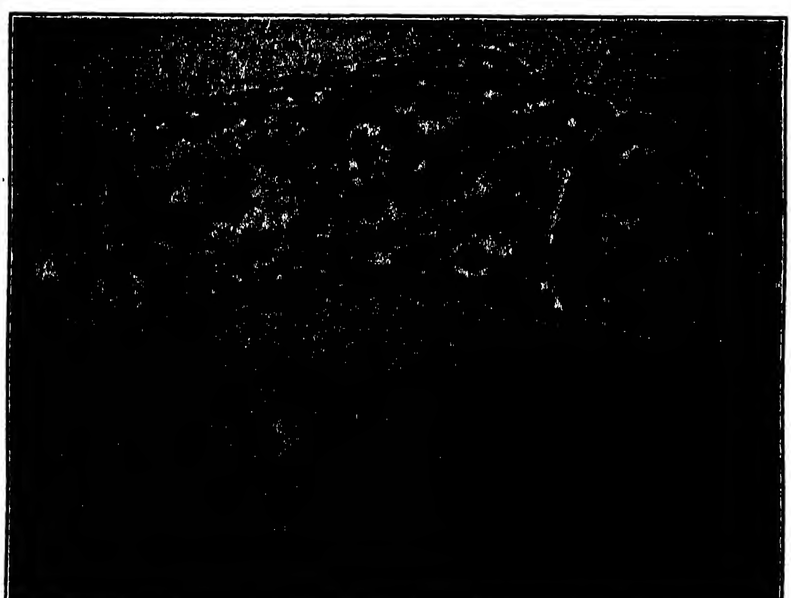

FIGURE 5. THE DELICACY AND DIMENSIONS OF THE PROTOPLASMIC LAYER LYING AGAINST THE CELL WALL. A. A CELL JUST BEGINNING TO SEND OUT A ROOTLET, B. A CELL WHICH HAS BEEN TREATED WITH 10 PER CENT. SUGAR TO CAUSE THE PROTOPLASM TO WITHDRAW FROM THE CELL WALL.

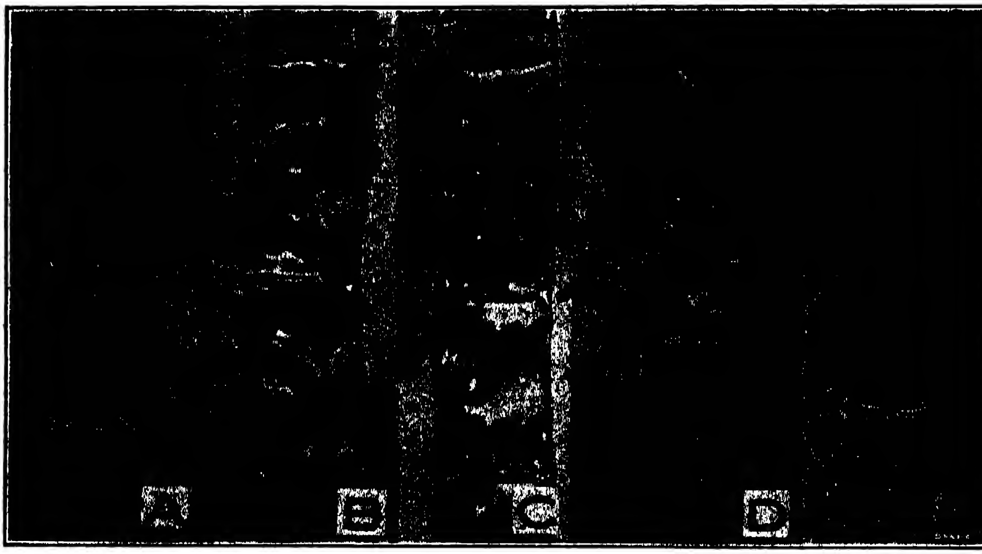

FIGURE 6. A–D. SUCCESSIVE STAGES IN THE GROWTH OF THE TUBE TO PERMIT THE TRANSFER OF THE MALE TO THE FEMALE SEX-CELL. FEMALE CELL BELOW IN A, ABOVE IN B, C AND D. IN D THE CELLULOSE PARTITION IS SWOLLEN AND BREAKING DOWN. E. A NORMAL SPORE COMPOSED OF FUSED GAMETES (ABOVE) AND TWO PARTHENOSPORES DUE TO FAILURE OF THE GAMETES TO FUSE THOUGH IN CONTACT.

C. E. Overton (1888), took no steps to prove the truth of it, which would have been difficult since it has turned out to be false. The essence of the idea as it then prevailed was that the process is a mechanically produced one, and that the gametes are passive. Against this unphysiological view Klebs took issue (1897) and thought to have found evidence that the male gamete condenses in response to a stimulus derived from the female. Whether this be true or not, and we can not yet say, Klebs did a good thing in insisting that, in his opinion, the whole process is a complicated physiological one, and this we now know to be the case. Klebs, in the course of his researches, made an important observation, namely, that just previous to conjugation the concentration of the sap of the gametes is reduced to nearly one half the usual value. This observation has recently been confirmed by Czurda and by myself, but Klebs was not led further into the problem and left it much as he found it. So far as I am aware no effort was made to explain the mechanics of condensation till Chodat (1910) advanced the theory that the gametes lose their power to retain the substances held in solution in the cell-sap, and in consequence lose also the power to retain the water in which these substances are dissolved. Chodat, however, did not determine if this were indeed the case, and I have recently shown that it is not, but quite the reverse. If this be true, the gametes must retain their avidity for water, which they do in the measure of the concentration of solution of their saps. In spite of this they can and do excrete water during condensation. The only remaining attempt to solve the problem is a recent one made by V. Czurda (1925), who took his point of departure from the observation of Klebs, above mentioned, arguing that the reduction of concentration of the sap becomes great enough to permit surface tension to come into play, separating the

protoplasm from the cell-wall and squeezing the contents of the male through the opening in the diaphragm, just as a soap bubble will contract when we cease blowing it up and allow the air to flow out—an exactly similar result due to the same conditions. At the time when the condensation takes place, however, the concentration of solution of the sap, while lower in the male than in the female, remains of value high enough so that water is taken up by it even during conjugation, as I have proved experimentally. Evidently there is something lacking even in Czurda's explanation, and this appears more certain when we know that the flow of male protoplasm into the female is not a steady movement but an oscillatory one, that is, the movement is frequently reversed. The normal total effect is a net result of condensations and enlargements of both gametes—the algebraic sum of plus and minus effects. How is this to be accounted for? The answer is, I venture to think, as follows.

During the period preceding fusion, not only does the concentration of cell sap go down—as Klebs found, to about 50 per cent. of the original value—but the male becomes attached to the partition wall separating the two gametes. This attachment serves as a point of leverage. Other changes occur which need not be considered here. When the time of fusion approaches—whether just before or at the time is not yet certain—the male contracts transversely at the end removed further from the female (figure 7b). It seems fairly certain that this contraction is not a passive matter, but active; that it is the same sort of contraction seen in other protoplasms. This phase of behavior lasts but a short time, or, if it continues, it is unobservable. So far as we can see, the only result of this contraction is the slight separation of the male protoplasm from the cell wall at the closed end and along the outer wall, but more at the distal than at the proximal end. One bit of evidence that this is true contraction is seen in the fact that the protoplasm leaves the closed end wall as if it were a cast, instead of immediately rounding off, as in figure 5b, as it should if the movement were passive. At the same time we know that the protoplasm has a

FIGURE 7. SERIES OF STAGES IN THE UNION OF THE GAMETES. A. THE FIRST AREA OF CONTACT AND FUSION IS SEEN. B. THE FIRST CONTRACTION OF THE MALE (BELOW). C, D AND E. SUCCESSIVE STAGES IN WHICH THE WATER EXCRETORY BLISTERS (CONTRACTILE VACUOLES) CAN BE SEEN.

higher viscosity here, that it yields to surface tension therefore only slowly. But if we apply a strong enough solution of sugar—it need be only slightly in excess of the concentration of the sap—the end rounds off more rapidly. Further, if we do this before fusion has occurred, the whole male protoplasm acts much as it does during contraction. While these evidences are not wholly convincing, the impression of active contraction is difficult to set aside.

As the contraction proceeds, a most remarkable phenomenon becomes apparent. At first a few minute bubbles appear in the very thin layer of protoplasm inclosing the sap (figure 7c), at first so small and few that they may quite escape notice, and earlier in the male than in the female, but normally always in both. These bubbles become gradually more numerous and larger, the earlier formed disappearing, the newer taking their places, till the whole of both gametes has the appearance of a froth (figure 7c). These bubbles are filled with water containing but little else. Their origin and growth is due to water taken by diffusion from the sap cavity; their disappearance to their bursting outwardly, emptying their contained water into the space between the protoplasm and the cell-wall (figure 8). The whole activity can be stopped at any time by a suitably concentrated solution of sugar. As a result of the constant formation of bubbles and their outward bursting, the amount of water in the sap cavity is constantly reduced, surface tension comes into play, and the contents of the male are forced through the opening into the female (figure 7 c-d). The process, which occupies one half to two hours, is most interesting and dramatic to watch. As soon as a few bubbles in the male have burst, the volume is seen to be smaller. Nothing further could happen, however, did not the female lose some of her volume in like manner. This permits a forward movement of male

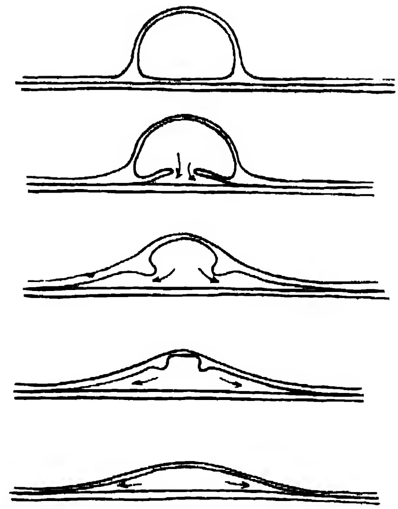

FIGURE 8. DIAGRAMS WHICH SHOW THE METHOD BY WHICH WATER IS EXCRETED FROM THE INSIDE OF THE GAMETES AND THROWN OUT BY THE BURSTING OF EXCRETORY BLISTERS (CONTRACTILE VACUOLES).

protoplasm. If the process of water excretion in the female slacks up at all, water will again be taken up and partially displace the male protoplasm, which then flows back. Normally the excretion of water is rapid enough so that the total forward movement of the male is in excess of the retreat. Soon the sap cavity of the male becomes so far reduced that it can pass in its entirety through the opening, the female in the meantime having suffered like reduction in volume. One may foretell such forward movements by noting the bursting of the excretory bubbles in the female. The reduction of volume and with it of surface of the male permits the more and more effective play of surface tension, and at length it completes its passage, the last portion often being composed of a protoplasmic spume. I have said nothing about the behavior of the chloroplast in the above description. This being green and quite easily visible, registers to the vision the movements which occur. Often a piece of it is pushed through the opening only to be withdrawn. When a considerable por-

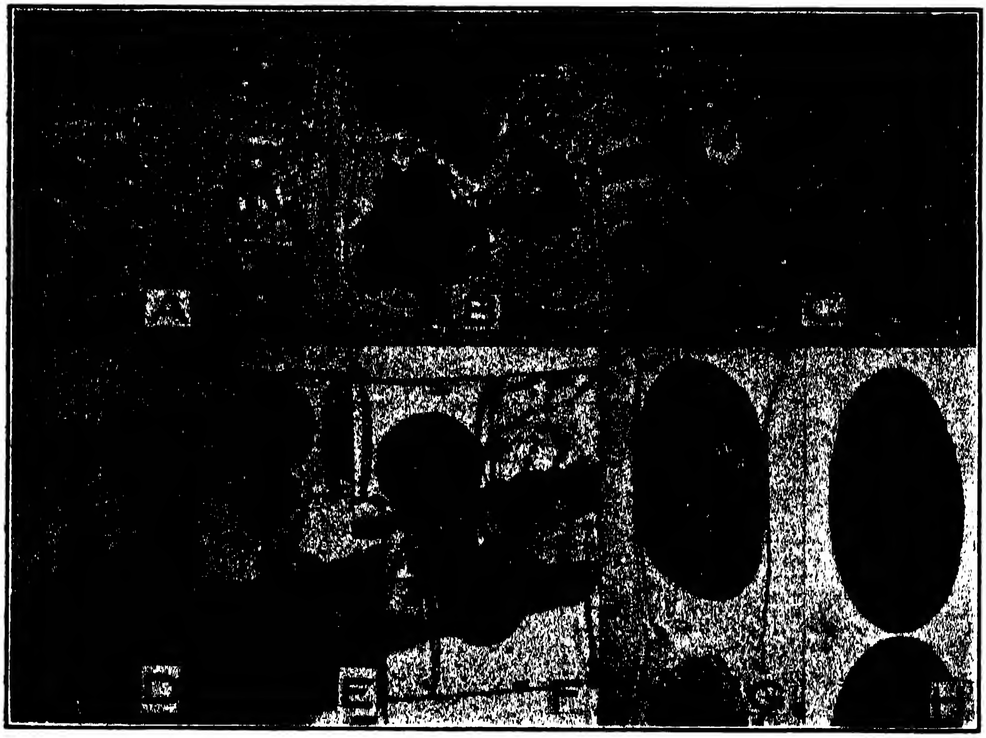

FIGURE 9. TRANSVERSE CONJUGATION. A–C. *Spirogyra varians.* THE CONTRACTILE VACUOLES MAY BE SEEN IN THE MALE (ON THE RIGHT). D–F. *Spirogyra maxima.* HERE THE REMARKABLE EARLY CONDENSATION OF THE GAMETES IS TO BE SEEN, AND THE POSITION OF THE MALE ATTACHED TO THE ENTRANCE OF THE CONJUGATION TUBE. A, BEFORE, B AT THE MOMENT OF, AND C, AFTER FUSION. G. SPORE SHOWING THE TWO SEX-NUCLEI JUST BEFORE FUSION. H. RESTING SPORE WITH THICK WALL.

tion has passed over, a reversal of flow may result in breaking it, or at all events in stretching it almost to the breaking point (figure 7d). The movements—stretching, folding and twining—of this plastic ribbon of green lend a strong dramatic element to the process.

The reader may now ask why the female does not flow toward the male or why a deadlock does not occur. Usually the male is smaller than the female, but not always, and then with no necessary interference with the usual procedure. In any event, the male condenses earlier and more rapidly and is anchored at the forward end, while the female remains turgid enough to stay anchored by mere volume, assisted by a previous bulging of the cell wall (figure 7).

After the male has passed entirely over, the combined protoplasms (the zygote, figure 7e) is still larger than it is in its final condition (figure 9g). The further condensation proceeds quite as before, until all the free sap has been discharged. The definitive form is fixed by the secretion of membranes (figure 9h) which remain entire till the time of germination.

What then are these bubbles? I have called them so because that is what they really are, only they go by another name in books, that of contractile vacuoles. They have long been known to occur in

the lower forms of animal life—in *Amoeba, Paramecium,* the *Heliozoa* and the like, and I have recently found them in the curious animalcule *Vampyrella* which feeds on *Spirogyra* alone, each animal having them in large numbers. They occur also in the motile forms of some of the lower plants, but they have never previously been observed in *Spirogyra.* But we are made aware of the fact that in the gametes of this genus—and we shall probably find them elsewhere—they are far more conspicuous both in numbers and size than in any other known forms.

In the preceding account the reader has been asked to consider only the kind of conjugation which proceeds between neighboring cells. It remains to indicate briefly the general character of the process when conjugation takes place between cells in neighboring filaments. Figure 9a shows the process at its inception. In some forms of *Spirogyra,* the whole procedure after fusion is in all essential respects like that above detailed (figures 9b–c). In others, however, the male gamete may condense a great deal before entering the transverse canal seen in figures 9d–f, and indeed the same condition may occur in the female as well. This condition is the one which dominated the thought of De Bary. It has been overlooked, however, that the male as seen in the figures remains attached to the neck of the conjugation tube, thus supplying the necessary leverage so that the pressure exerted at the decreasing surface of the male may urge the protoplasm through the opening. Fusion of the male and female is accomplished only if, by crowding (figure 9e), the surfaces come into contact and again if the surface tension conditions are favorable.

Although the purpose of this paper has been achieved, there remain, among many further details, two points which will naturally occur to the reader, namely, the fate to the chloroplasts and of the nuclei. If nothing happened, there would be an accumulation of both these organs resulting from the union of gametes.

Like the gametes themselves, their nuclei also fuse slowly to form one. This fact we know, but the details we are ignorant of. Figure 9g shows the two nuclei in contact but before actual fusion.

The chloroplasts, however, behave in one of two ways. Those of the male gamete degenerate in the zygote (Chmielewski, Troendle) or they unite with those in the female by fusion (Overton), at least these two views are held at present. At all events the number of chloroplasts remains constant.

ORGANIZATION AND VARIATION IN PROTOZOA

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A FAVORITE analogy of the late Dr. Loeb was to liken the cell to a chemical machine in which, through oxidation and other chemical processes of metabolism the chemical energy of organic compounds is utilized and represented by a multitude of activities which we regard as vital manifestations. The same idea is expressed by Professor Wilson, who writes in "The Cell": "We assume, as our fundamental working hypothesis, that the specificity of each kind of cell depends essentially upon what we call its organization, *i.e.*, upon the construction of the cell machine, in some sense or other—morphological, physical or chemical" (p. 635). Let us take as our point of departure the conception of a protozoon as a machine-like organism, with a visible organization expressed by definite and characteristic cell structures, and with activities which represent the same fundamental vital functions that every living thing performs. The adult structures which we actually see are the final product of the possibilities of any particular organization. They differ in different genera and in different species of the same genus, but are apparently identical in all examples of the same species. These are the characters which afford a basis for the so-called natural classification of the Protozoa, and they are the most evident of the structural peculiarities of any given type.

Other structural evidences of organization are not usually visible in an organism in its living state but are more or less prominent in properly made preparations. Here the nuclei and kinetic elements are visible evidence of organization which have been the subjects of study by a great number of observers who are interested primarily in cytology of the Protozoa. Basal bodies of flagella and cilia, blepharoplasts, centrosomes, centrioles, coordinating fibrils and neuromotor systems of all kinds, together with plastids and metaplastids, furnish additional evidence of the particular organization of the cell.

Apart from these more or less easily visible evidences of organization, which may be termed the *derived organization*, is the fundamental, invisible and entirely unknown organization of the protoplasm of the cell. The visible evidences may disappear at times or may be temporarily altered, but from the invisible *fundamental organization* they are again reformed or restored to their characteristic and specific types.

This fundamental organization which gives rise to the specific, visible structures in each type of Protozoa may be conceived as due to the particular kind and arrangement of the colloidal substances—proteins, carbohydrates, fats, mineral elements in the form of salts and water—which make up protoplasm. The particular composition (*e.g.*, specificity of the proteins) and arrangement of such substances are presumably different in different species and are probably more or less different in individuals

of the same species; and there is abundant evidence to show that they vary at different times in the same individual. In the last analysis what I mean by the term organization is this unknown but specific combination of protoplasmic substances.

It is in this ultimate organization that the potentialities, both structural and functional, of a species are contained, and so long as the complete organization is represented, any small bit of the protoplasm is capable of forming the whole. Here are two organisms, A, a *Stentor polymorphus*, B, a *Uroleptus mobilis;* their visible organizations are entirely different. If we cut a small piece from the *Stentor*, this piece rounds out into a homogeneous ball. If we cut a similar piece from *Uroleptus*, this piece likewise rounds out in an apparently homogeneous ball. If the two balls are of similar size there is no visible difference between them. Yet they are quite as different as the adult *Stentor* is different from the adult *Uroleptus*, and in the proper medium the one develops into a perfect *Stentor*, the other into a perfect *Uroleptus*. The characteristic specific organization is present in each such fragment, and the developed organism is the expression in a structural and functional sense of these organizations. The problem to the student of variation is: Can this fundamental organization be permanently changed so that it will give rise to adults with visible structures and activities of different types from the normal species?

These organizations, visible and invisible, are the chemical machines which do the work of living. In an appropriate medium in which oxygen, free or combined, is of the first importance, the various substances of protoplasm begin a series of coordinated and correlated chemical and physical activities manifested by movement, by feeding and the sequential processes of nutrition, by excretion of waste, by growth and ultimately by reproduction. The organization is active in all its parts.

Living things are not thus active at all times, even in the presence of oxygen and abundant food. There may be long periods in which the machine is static and the constituent parts inactive in the usual metabolic sense. In our descriptions we are accustomed to pass over such phases rather hastily or to ignore them altogether. But they are worthy of careful consideration. I refer to the various phases of encystment of flagellates and ciliates, to sporocysts and spores of Sarcodina and Sporozoa. It gives me no satisfaction to pass these by as arrested stages in metabolism, or as stages in which protoplasmic activities are in abeyance or reduced to a mere trace of the usual metabolic activities. The protoplasm is here enclosed in an impenetrable wall of chitin, and when dried oxygen and water are inaccessible. An encysted ciliated protozoön is a homogeneous ball of protoplasm enclosed in such a cyst membrane. There is absolutely no structural evidence of the species to which the ball belongs unless the cyst wall has some peculiarity of structure by which it can be recognized. In this condition the ball may remain unchanged for months or years in a dried state. Without distorting beyond recognition the usual conception of metabolism there is no evidence of vital activity in such encysted forms. There is probably molecular activity as in all substances, but no metabolism as usually understood. There are no waste products, there is no evidence of irritability, and no change in that ball of protoplasm, at least no change that can be recognized. The same is true of a spore or a seed that remains in the dried condition for months or years; and the same is true of a dried rotifer. For several years I had a bottle of dried dust in the form of amorphous particles on my shelf

at Columbia. From time to time I would take out a pinch of this dust and drop the particles into a culture dish of water. In a very short time the water would be teeming with fully formed rotifers in full activity, as many of them as there were particles introduced.

This phenomenon can mean only one thing, *viz.*, that the dried particles were living rotifers; that life was there all the time and that the organization was unimpaired. Similarly with our seeds, spores or encysted ciliate; they are alive all the time; their organizations are perfect, but in this state the constituent parts of their protoplasm are inactive. Here then it is the organization that persists; it is the organization that is continuous and has been continuous through historic and prehistoric ages, and barring accidents has the potential of an indefinitely continued existence in the future. There seems to be no alternative for the conclusion that what we call life, in the sense of perpetuity at least, is the same thing as that which we call organization in its modern and physical interpretation.

We are accustomed to speak of life as dynamic; as force; as protoplasm in action; and in the next breath to speak of life as continuous from protoplasmic beginnings down to the present time. At such times are we not speaking loosely? Do we mean exactly what we say? I think not. Is the automobile going forty miles an hour the same thing as it is when standing in the garage? Its organization indeed is the same, but in the garage the constituent parts, while all in their proper places, are quiet and inactive. Introduce oxygen, give it gasoline and add a spark; oxidation occurs and through the transformation of energy the parts of the engine move; turn a lever, connect the engine with the transmission and the whole mechanism moves, and the more food we give the engine the faster goes the aggregate. Here the many parts are so put together that they interact harmoniously; they are properly correlated and coordinated and a smoothly running car is the result. The many different car organizations on the road are all performing the same fundamental functions, but their organizations are different. Now the activity of the car is not permanent; its movements are not permanent; that which is permanent is its organization.

This crude analogy will illustrate what I should like to present as a distinction between life and vitality. Life, as we have seen, is inseparably bound up with organization; and what we ordinarily mean by continuity of life is continuity of organization. Vitality I would define as the sum-total of the activities performed by the organization. Vitality is the dynamic phase of life; it can be studied and measured; but it is not continuous, at least not in the group of organisms of which I am speaking. Life, on the other hand, can not be measured; as organizations we know little about it; but life is continuous. The dried rotifer, the cyst or the spore has life and has the possibility of vitality so long as its organization is retained. Let the organization disintegrate by surface oxidation, by continued molecular activity, or through other agencies and the seed will not develop, the spore and the cyst will not germinate, the dried rotifer will never again spread its fascinating wheels.

Here, however, the analogy ends and we are forced to abandon the conception of a machine in relation to the functioning organism. When vitality begins; when the constituent parts are in the full activity of metabolism, the organization is no longer fixed, but each substance in it is subject to changes brought about by its own activities. The encysted protozoon in its dried state is undifferentiated; it consists of substances in the arrangement of the fundamental organi-

zation. Under proper conditions water and oxygen are absorbed through the cyst membrane and the ball of protoplasm begins to differentiate. Changes are first observed on the periphery and, presumably as a result of oxidation, the characteristic motile organs, absent until now, are differentiated from the cortex. Cortical apertures, mouth and anus are formed, and the normal shape of the body is assumed, all within the still unbroken but now permeable cyst wall. The active organism, with its motile organs in full swing, breaks through its walls and begins its vegetative life as a highly labile, animated bit of protoplasm with all the initial visible differentiations of its type.

This phenomenon of differentiation from the apparently homogeneous ball of protoplasm may well be included in the category of ontogenetic or developmental processes. It is the evolution or consecutive unfolding of the potentialities of the organization and is characteristic of all encysted Protozoa. Under other conditions, and when encystment is not involved, differentiation is not so rapid but resembles processes of regeneration, as with the cut fragments of *Stentor* or *Uroleptus*. So it is with young organisms formed by budding or by multiple division; in these small bits of fundamental organization processes of differentiation are relatively slow and are apparently dependent upon metabolism and growth. Thus the bud of an *Acanthocystis*, according to Schaudinn, requires from five to six days of growth before the full expression of the *Acanthocystis* derived organization is attained. Or a polycystid gregarine requires days of feeding and growth before it changes from the undifferentiated sporozoite to the differentiated adult form. A multitude of similar examples might be selected from the enormous list of known Protozoa, but these two cases will illustrate what I mean by the statement that the organization becomes differentiated as a result of its own activities. Not only is this difference expressed by structures in the adult which were not present in the young form, but it is highly probable that changes in the fundamental organization or invisible differentiations have gone on as well. I have previously used the phrase interdivisional differentiation to characterize this phenomenon and have illustrated it with the merotomy experiments on *Uronychia* by Dr. Young and by myself. Two individuals of *Uronychia transfuga*, one five hours old, the other twenty hours old, appear to be identical, but if we transect each the fragments do not behave in the same way in respect to regeneration. The emicronucleate fragment from the young individual will not regenerate at all; but the emicronucleate piece from the older individual regenerates a perfect individual but without a micronucleus. Something in the organization has changed during the twenty-hour interval of metabolic activity, some differentiation of the organization has occurred whereby the older enucleated fragment is able to restore a completely differentiated individual by regeneration.

Furthermore, this change or differentiation, whatever it is, is lost with the processes of division, which, in my experiments, occurred once in approximately twenty-six hours. The young cell has now lost the power to regenerate in the absence of the micronucleus and does not regain this power until late in interdivisional life. It looks very much as though the differentiated organization were thoroughly cleansed of the accumulated products of differentiation by the processes at division, or, to use Child's expression, had been dedifferentiated and restored to the labile condition characteristic of the young organism.

There is abundant evidence of such differentiation and dedifferentiation in

the different classes of the Protozoa. In many cases metaplastids are formed as a result of metabolic activities and these, in the gruelling processes of cell division, are thrown off or absorbed. Not only metaplastids but functional structures are often similarly discarded or absorbed. Amongst the flagellates we have numerous examples of the discarding of flagella and other kinetic elements at division. For example, in *Lophomonas blattarum* the great brush of flagella with their basal bodies, blepharoplasts and axial strand are all discarded and the full complex is reformed for each of the daughter cells. It may be significant that this regeneration occurs in a protoplasmic region far removed from the site of the old complex. In ciliates, easily observed in the more complex forms like the Euplotidae, there is a similar absorption of the whole complicated motile apparatus and a regeneration of a double set of undulating membranes, membranelles and cirri which are thus at all times commensurate in size with the size of the young cells. In multiple division, also, accumulated products of activity are left out entirely from the protoplasm of the young organisms, as in the familiar case of different species of *Plasmodium* and other hemosporidia where the melanin granules are discarded with a residuum of protoplasm at the time of division.

If the visible differentiations are thus discarded at division, to be formed anew, it requires no hypertrophied credulity to believe that analogous processes of housecleaning at division periods are taking place in the general organization and that, as a result, the products of cell division are not only youthful organisms but possess an organization which is essentially different from that of the old parent cell from which they came, and a lability which is characteristic of an organism fresh from a cyst. In short, division of the cell involves processes which bring about a more or less complete reorganization of the protoplasmic substances. The cell is apparently restored to the condition of its fundamental organization from which two young organisms immediately develop their visible evidences of organization anew.

Here, as I believe, is the possibility of the explanation of some of the results of isolation cultures in which no definite life cycle has been observed. The long-continued culture of *Actinophrys sol* by Bêlar, the even longer culture of *Eudorina elegans* by Hartmann, the incomplete culture of *Glaucoma scintillans* by Enriques, the upwards of 2,000 generations of transplants of fibroblasts in tissue cultures by Carrel and Ebeling, all may have their explanation in the periodic reorganization which occurs at cell division and the restoration of vitality which accompanies that reorganization. Here, too, is a possible explanation of the continued existence of animal flagellates and many of the plant flagellates which so far as we know never undergo processes of fertilization. It is possible also that conditions of the milieu may be so prepared that the organism is helped or injured at these critical periods and that it will live longer or shorter under such isolation cultures without endomixis or conjugation than it will live under the usual environmental conditions.

In the majority of ciliates in culture, in Sporozoa and in Foraminifera, continued successive divisions bring unmistakable evidence of waning vitality, and, without endomixis or fertilization, ultimate death. I have outlined my views on the rejuvenating effects of conjugation so often that I will not review the evidence here. I will merely point out again that with fertilization by conjugation there is an even more drastic overhauling of the old organization, a discarding and absorption of the old cell

organs, including the macronucleus, that have survived many a division, and a reorganization that restores the cell to the young, labile condition characteristic of young forms fresh from their cysts. Whether this waning vitality and ultimate death is due to the accumulation of products of metabolism as suggested by Minot, and later by Child, or whether it is due to a progressive modification of the organization itself is not known. There is some evidence, which I will briefly outline, that it is due to the latter.

In old age protoplasm in isolation cultures not only is there a great retardation of metabolic processes as shown by the rate of division, but the division processes themselves are pathological in a large percentage of cases, and monsters of fantastic shape and frequently of huge size are formed. This indeed might be explained as due to the accumulation of waste matters which hinder normal processes. But similar old individuals will conjugate and such conjugations are followed by the usual accompanying phenomena of reorganization. The offspring thus produced, however, in the majority of cases, are short-lived and have a weakened vitality throughout. It may be significant, however, that occasionally the progeny from such old age individuals have a remarkably high vitality. Thus in *Uroleptus mobilis* one ex-conjugant from parents in the 225th generation—parents which had only thirty-two more generations before they died from exhaustion—lived for 643 days and divided 597 times. This case, Series 19 in my experiments, was a remarkable exception to the majority of my 128 other series of *Uroleptus,* few of which live more than 250 days and few divide more than 300 times. It is a still more remarkable exception to other cases of ex-conjugants from old age parents where the length of life is rarely more than fifty days. In such cases the old organization is so changed that reorganization is impossible or incomplete. It is theoretically possible to explain the unusual case as due to the fortunate combination of highly modified organizations brought about by long-continued metabolism and division. In no case, however, have such exceptional series given rise to offspring with a similar exceptional vitality.

Other evidence of a changed organization with age is shown by Sporozoa, particularly by the gregarines and the Neosporidia, and by the Mycetozoa amongst the rhizopods. Here, new structures appear in the organization which are formed only in the very last stages of life of the individual. In this connection I will enumerate only the sporoducts, cyst walls and polar capsules of the Sporozoa, or the capillitia, elaters and similar final structures of the Mycetozoa.

Further evidence of progressive change of the organization with continued metabolism is furnished by the multiple phenomena of gamete formation. No protozoön is mature immediately after fertilization. With Sporozoa and Foraminifera and many flagellates gamete formation is the final expression of a modified organization. In Infusoria gametes are rarely formed, but individuals appear after variable periods in different ciliates which are mature and ready for conjugation. The onset of the change in organization which makes gamete formation or conjugation possible is sudden and is advertised by no peculiarities of structure or function. Yesterday thousands of *Uroleptus mobilis* in a container showed not one pair of conjugating individuals; to-day fully 90 per cent. in that container are conjugating. The environmental conditions have something to do with the change, but unless the protoplasm is in the appropriate condition of organiza-

tion, such environmental factors will be ineffective.

With gamete-forming types this change which we call maturity is fatal; the gametes apparently have lost their metabolic powers and without fertilization they die. Their differentiations are antithetic and apparently complementary, for with their union, vitality is completely restored and a young labile organism results. With ciliates the change in organization is not so sudden but appears to be progressive and failure to conjugate at any given time is not immediately fatal. This is easily demonstrated by separating two individuals which have just begun to conjugate. With *Uroleptus,* however, such separation does not prevent the reorganization that accompanies complete conjugation and a new, young, labile organism results.

This latter phenomenon is of the same nature as the asexual reorganization in *Paramecium* discovered by Woodruff and Erdmann in 1914. Its discovery marks the culmination of the brilliant work of Woodruff on *Paramecium aurelia* which he began in 1907. It is a periodic process of reorganization, parallelling the reorganization processes of conjugation and involves deep-seated changes in the organization which result in a youthful and labile individual. In *Paramecium,* except for depression, there is no external evidence of the processes going on within. In other ciliates this process, called endomixis by Woodruff and Erdmann, precedes and accompanies the first stages of encystment, so that endomixis is advertised by a permanent cyst. As we have seen, when the organism emerges from its cyst it is young, labile and vigorous.

The changes in organization which have been described thus far are all normal reactions to the protoplasmic activities going on within the organism. They are repeated by every individual of the species and follow the same sequence in a normal life history. They represent, therefore, the complete normal expression of the potentialities of a given organization, called forth by the chemical and physical interactions of the constituent substances in protoplasm and by the interactions of these substances with the environment. Renewal of vitality, which accompanies reorganization, may be brought about by division, by fertilization or by parthenogenesis. Some of the processes may be inhibited by changes in the environment or some may be hastened by appropriate changes. Thus the onset of conjugation may be induced by certain salts in the medium according to the experiments of Zweibaum, of Jollos, of Baitsell and others.

Now the interesting problem arises: Is it possible to so modify the environment that the fundamental organization of a protozoön becomes permanently changed and in such a way that variations in the derived organization are produced which will be perpetuated? A great many experiments have been undertaken in connection with this problem, some dealing with modifications of the environment, some with modifications of the protoplasm itself. The general result of all such experiments has been to demonstrate the extreme difficulty with which the protoplasmic organization can be changed in any permanent way. Let me cite a few examples to illustrate this difficulty.

In nature there are many cases in which change in environment has not resulted in a permanent change in the organization. Thus a drastic change in environment is introduced when the malaria-causing organisms *Plasmodium* and *Haemoproteus* species are inoculated by their definitive hosts, mosquitoes, into human or bird blood. An entirely new series of reactions and structures are expressed by the old organization and the change is persistent

so long as the parasites remain in the new environment. But the change is not permanent and some of the fundamental and necessary processes for continued life of the parasites are apparently impossible in the vertebrate hosts. For these the parasites must return to the mosquito. Many analogous instances might be given. The vegetative life of the Coccidian *Aggregata eberthi* is passed in the intestine of crabs; but for full development such crab parasites must be taken up by cephalopod molluscs; the giant gregarine *Porospora* has no permanent organization as such in the digestive tract of the lobster, but ultimately dies if not swallowed by the mussel *Mytilus*. It is probable that complete adaptation and a permanent change in organization is represented by the great majority of gregarines, coccidia and neosporidia which undergo their full cycle of development, sexual and asexual phases, in the same host.

Human experiments of analogous type have been less successful than these natural ones. It is quite possible to apparently change the organization by changing the environment. *Amoeba verrucosa* of fresh water becomes quite a different type of organism when transferred to sea water and will reproduce this type as long as it is kept in sea water. But transfer it back to fresh water and its organization will be found to have lost none of the characteristics of *Amoeba verrucosa*. The genotype is unchanged. In a similar way organizations of different species when subjected to chemical or temperature changes of the medium may be gradually educated to perform their vital activities while in the changed environment. We call it adaptation and we are only beginning to realize the possibilities of protozoon organizations to adapt themselves to such changed conditions. But the changes are not permanent; they are what Jollos has aptly termed *enduring modifications*, and in the majority of cases restoration to their habitual environment restores their usual organizations. With parasitic forms so-called poison-fast races have been known for years. Atoxyll-fast or arsenic-fast Trypanosomes, mercury-fast spirochetes are examples of such adaptations to poisons. Quinine-fast Plasmodia are probably responsible, as Bignami first pointed out, for enigmatical relapses in malaria. In all such cases, again, reversion to the normal occurs with restoration to the usual media or to the definitive host. In some cases these changes involve structural modifications which are visible. Thus Werbitzki obtained trypanosomes without the usual parabasal body by adding pyronin to the culture medium and after the treatment had been stopped such races lived for many generations of transplants with no trace of this kinetic element. Ultimately, however, with passage of these trypanosomes through the invertebrate host, the parabasal body reappeared. A very amazing result has been obtained recently by Hartmann with *Eudorina elegans*, a 32-celled globular colony, and with *Gonium pectorale*, a 16-celled flat colony. By the addition of nitrogen salts, particularly ammonium chloride, to the medium he changed *Eudorina* into *Gonium;* and a normal *Gonium* into a *Eudorina*. Here was a complete change in organization, so complete indeed that two widely different genera were interchanged. But the change lasted only so long as the unusual salts were in the medium and if the interchanged genera were replaced in normal pond water, each reverted to its characteristic organization.

In another group of experiments attempts are made to change the organization while the environment remains normal. Here, again, as with the preceding group, the organization in the majority of cases is not permanently altered.

Such experiments may involve the cytoplasm alone or the nucleus; if the latter, there is some evidence of permanency; if the former, no evidence at all. Thus mutilations are passively handed down to progeny by division. We may cut a *Paramecium* through the anterior or the posterior third; the cut surface is soon replaced by normal cortex, but the cell is truncated and quite unlike the normal. When it divides it forms a small truncated cell and a full-size normal cell. The normal cell continues to form normal cells by division and the truncated cell in the majority of cases will continue to form one normal and one truncated individual for three or four generations, but there is a gradual regeneration of the lost part until finally the original truncated cell gives rise to perfect cells. In some cases, however, such truncated cells have lost something in the organization that is essential for reproduction. They will grow and attempt to divide, but division is incomplete and a monster results. Repeated abortive attempts to divide result in the formation of many mouths and peristomes; in one such monster I counted eighteen mouths. Such things may live for weeks, but they ultimately die. In such cases we succeed in mutilating the organization to such an extent that normal coordinations are lost and a return to the normal is impossible. Similar monsters are characteristic of old-age cultures of ciliates.

Artificially produced spines or processes or clefts in the cortex may be handed down passively to descendants by division, but such mutilations are soon healed, leaving no trace of their former existence, and no change in organization.

Or it is possible to change the relative proportions of substances in the organization. Popoff, for example, centrifuged a *Stentor* when about to divide producing individuals in which the original beaded nucleus was unequally distributed, one individual receiving sixteen beads, another only three. Both reorganized perfectly, but the second individual was only one quarter the size of the first. After a few days both individuals had the same number of beads. In another case a dividing *Stentor* was suddenly cooled so that the division processes stopped and the normal form was resumed. Replaced in its normal medium it became a giant *Stentor* and a temporary race of giants was formed by division. An analogous experiment was made by Chatton on the ciliate *Glaucoma scintillans*. By treating individuals in the early phase of division with dilute solutions of sodium bromide for a few minutes and then replacing them in their normal medium he obtained individuals with two complete sets of cellular organs, two mouths, two peristomes, two vacuoles, etc., but with only one macronucleus. These double individuals upon division produced similar double individuals and continued to do so for a period of five months when the culture was abandoned. Analogous double individuals obtained by Dawson were fused back to back and in one culture such a pair of *Oxytricha hymenostoma* was carried through 102 generations by division. A third illustration occurred in a culture of *Uroleptus mobilis*. Two individuals not only failed to separate after conjugation and subsequent reorganization, but fused throughout the entire length of the body, forming a single bilaterally symmetrical individual with two complete sets of cellular organs. It reproduced through 367 generations by division and lived more than fourteen months. Here there was a distinct change in organization and a change whereby some of the diagnostic features of *Uroleptus* were lost and new features formed. Thus the macronucleus became so modified that it would not be recognized as a *Uroleptus*

nucleus, becoming a broken ellipse in form. With the novel organization, however, was a limitation of function. The double organism had apparently lost the power to encyst; nor would the most tempting conditions of the environment induce them to conjugate. The principle of monogamy had been apparently established in one case at least of the ciliates, but it was fatal; the two individuals lived together and they died of old age together, a beautiful Darby and Joan existence.

The upshot of all such observations and experiments is the demonstration that the organization of these unicellular organisms is fixed for each species and can not be altered in any permanent way by crude artificial changes of the environment or by any equally crude mutilation of the protoplasmic architecture. The permanent changes that occur come from within the organization itself.

The variations that arise from within the organization may be induced or at least furthered by external help from the investigator. Thus Jollos found that variations in function and structure of *Paramecium* could be established by treatment with arsenic acid or with high temperatures, provided these abnormal conditions were introduced at what he calls the "sensitive period" immediately after conjugation. Thus immunity to high percentages of arsenic and increased size of the cell were conditions which persisted through several successive periods of endomixis and through two successive conjugations. In these respects it appears that Jollos has come rather close to producing mutations. A more definite mutation has recently been observed by Professor Mary S. MacDougall. In a pure line of *Chilodon uncinatus* she observed that the usual form was being replaced by a larger and a sturdier race of *Chilodons* but with structures otherwise of *uncinatus*. Cytological study of these forms, particularly during conjugation and division, showed that the ordinary diploid race of *Chilodon* was the original race under cultivation and was characterized by four chromosomes, while the new race was a tetraploid form with eight chromosomes. Here a change in organization had been effected by a change in one of the fundamental components of the protoplasmic make-up. Under what conditions, how or when the change occurred is entirely unknown.

Still another method of obtaining well-marked variations in organization is the method of selection. The splendid work of Jennings and his associates along this line has demonstrated that the sifting out of germinal characteristics and establishment of definite and varied types of structure through uniparental inheritance is no theory but a fact established by patient research. In this connection I need only recall the work of Jennings on *Difflugia corona;* of Hegner and of Reynolds on *Arcella* and of Root on *Centropyxis*. Whether or not, as Jollos points out, such variations represent a permanently changed genotype can not be determined from any of this work. For such determination we must have the results of reorganization which follow the fertilization of gametes from gametocytes of a given selected line.

We have little doubt, *a priori*, that variations may and do arise from the union of germ plasms in Protozoa as in Metazoa. But there is singularly little evidence of this along experimental lines that will bear analysis. I am aware of only one experiment that will stand the test of criticism and even this should be confirmed before we can accept it as conclusive. I refer to the experiments on Mendelian segregation in the hands of Adolph Pascher, who succeeded in crossing two incompletely identified species of *Chlamydomonas*. Of the four products of the zygote, one was like species A, one like species B and two had new

organizations representing diverse combinations of characters of A and B. Here again was evidence of the sifting out of germinal characters presumably by zygotic meiosis and with such germinal sorting the origination of new types of organization.

In conclusion, I would point out once more that organization in Protozoa is as definite and as fixed as it is in any type of living things; that it is represented by visible structures which are not only temporary but are subject to changes with metabolic activities. These visible structures are replaced and formed anew at conjugation or fertilization generally or by parthenogenesis; and they are formed anew at periods of cell division. With fertilization, with endomixis, and with cell division there is evidence that the cell is completely reorganized and that the fundamental, invisible, organization starts with a clean slate after each and every one of these deep-seated phenomena.

I have also endeavored to show that gamete formation and the period of maturity in ciliates is evidence of a cumulative differentiation of the protoplasmic substances; that gametes are so modified that without fertilization or its equivalent they can not live and that ciliates without conjugation or endomixis in the majority of cases will live only with weakening vitality which ends in death.

Finally let me repeat once more: what we ordinarily mean by the term "life" is protoplasmic organization. Just what this is we do not know; it can not be measured with our present means of measurement; it is continuous and has been continuous since the remote past and will continue indefinitely in the future. Vitality is the activity of the organization; it can be known and measured; it is known and measured in large part; it is discontinuous. Death is not of necessity the cessation of vitality; death occurs only with disintegration of the machine. When this occurs with any single individual acting as trustee for the specific organization, there are myriads of other trustees which will carry that organization on and into the future.

RADIO TALKS ON SCIENCE[1]

THE ETHER-DRIFT EXPERIMENTS OF 1925 AT MOUNT WILSON

By Professor DAYTON C. MILLER

CASE SCHOOL OF APPLIED SCIENCE

THE general acceptance of the theory that light consists of a wave motion in a luminiferous ether made it necessary to determine the essential properties of the ether, which will enable it to transmit the waves of light and to account for optical phenomena in general.

Several physicists have sought to prove the existence of a stationary ether by direct experiment. The most fundamental of such proposals was that of Professor A. A. Michelson, made in 1881, based upon the idea that the ether as a whole is at rest and that light waves are propagated in the free ether in any direction and always with the same velocity with respect to the ether. It was also assumed that the earth in its orbital motion around the sun passes freely through this ether as though the latter were absolutely stationary in space. The experiment proposed to detect a relative motion between the earth and the ether, and it is this relative motion which is often referred to as "ether-drift." A remarkable instrument known as the "interferometer," which has been invented by Professor Michelson, is capable of detecting a change in the velocity of light of the small amount involved in ether drift.

In the year 1887, at Case School of Applied Science, in Cleveland, Professor Michelson, in collaboration with the late Professor Edward W. Morley, of Western Reserve University, made certain important developments of method and apparatus and used the interferometer in the now famous "Michelson-Morley Experiment," in an effort to determine whether the motion of the earth through space produces the effect upon the velocity of light as predicted by theory.

In November, 1887, they announced their conclusions as follows: "Considering the motion of the earth in its orbit only . . . the observations show that the relative motion of the earth and the ether is probably less than one sixth of the earth's orbital velocity and certainly less than one fourth."

In 1895 Lorentz and FitzGerald suggested that the motion of translation of a solid through the ether might produce a contraction in the direction of the motion, with extension transversely, the amount of which is proportional to the square of the ratio of the velocities of translation and of light, and which might have a magnitude such as to annul the effect of the ether-drift in the Michelson-Morley interferometer.

The writer, in collaboration with Professor Morley, constructed an interferometer about four times as sensitive as the one used in the first experiment, having a light path of 224 feet, equal to about 150,000,000 wave lengths. Such an instrument with a base made of planks of pine wood was used at Cleve-

[1] Broadcast from Station WCAP, Washington, D. C., under the auspices of the National Research Council and Science Service and the direction of W. E. Tisdale.

land, in 1902, 1903 and 1904, for the purpose of directly testing the Lorentz-FitzGerald effect, but the changes in the wooden frame due to the variations in humidity and temperature made accurate observations difficult to secure. A new supporting frame was constructed of structural steel and was so arranged that the optical dimensions could be made to depend upon distance-pieces of wood, or upon the steel frame itself. Observations were made with this apparatus in 1904. The results were expressed as follows: "If the ether near the apparatus did not move with it, the difference in velocity was less than 3.5 kilometers a second, unless the effect on the materials annulled the effect sought. Some have thought that this experiment only proved that the ether in a certain basement-room is carried along with it. We desire to place the apparatus on a hill, covered only with a transparent covering, to see if an effect can be there detected."

In the autumn of 1905, Morley and Miller removed the interferometer from the laboratory basement to a site on Euclid Heights, Cleveland, at an altitude of about three hundred feet above Lake Erie, and free from obstruction of buildings. Five sets of observations were made in 1905–1906, which give a definite positive effect of about one tenth of the then "expected" drift.

It was at this time that Einstein became interested; and in November, 1905, he published a paper on "The Electrodynamics of Moving Bodies." This paper was the first of a long series of papers and treatises by Einstein and others which has developed into the present theory of relativity. In the first paper, Einstein states the principle of constancy of the velocity of light, postulating that for an observer on the moving earth, the measured velocity of light must be constant, regardless of the direction or amount of the earth's motion. The whole theory was related to physical phenomena, largely on the assumption that the either-drift experiments of Michelson, Morley and Miller had given a definite and exact null result.

The deflection of light from the stars by the sun, as predicted by the theory of relativity, was put to the test at the time of the solar eclipse of 1919. The results were widely accepted as confirming the theory. This revived the writer's interest in the ether-drift experiments, the interpretation of which had never been acceptable to him.

The site of the Mount Wilson Observatory, near Pasadena, California, at an elevation of about six thousand feet, appeared to be a suitable place for further trials. An elaborate program of experimentation was prepared.

Observations were begun in March, 1921, using the apparatus and methods employed by Morley and Miller in 1904, 1905 and 1906, with certain modifications and developments in details. The experiments have been continued till the present time.

Throughout all these ether-drift experiments, at Cleveland and at Mount Wilson, there persisted a small but very *definite positive effect*. In spite of long-continued efforts it was impossible to account for these effects as being due to terrestrial causes or to experimental errors. Very extended calculations were made in the effort to reconcile the observed effects with the accepted theories of the ether and of the presumed motions of the earth in space. The observations were repeated at certain epochs to test one after another of the hypotheses which were suggested. At the end of the year 1924 a solution seemed impossible.

Previous to 1925, the Michelson-Morley experiment has always been applied to test a specific hypothesis. The only theory of the ether which has been put to the test is that of the absolutely stationary ether through which the earth moves without in any way disturbing it.

To this hypothesis the experiment has given a negative answer. The experiment was applied to test the question only in connection with specific assumed motions of the earth, namely, the axial and orbital motions combined with a constant motion of the solar system towards the constellation Hercules, with the velocity of nineteen kilometers per second. The results of the experiment did not agree with these presumed motions. The experiment was applied to test the Lorentz-FitzGerald hypothesis; that the dimensions of bodies are changed by their motions through ether; it gave a negative answer to this. It has been applied to test the effects of magnetostriction, of radiant heat and of gravitational deformation of the frame of the interferometer. Throughout all of these observations, extending over a period of years, while the answers to the various questions have been "no" there has persisted a constant and consistent small effect which has not been explained. Not until the present year, 1925, has a general question, not based upon a specific hypothesis, been put to the test.

The ether-drift interferometer is an instrument which is generally admitted to be suitable for determining the relative motion of the earth and the ether, that is, it is capable of indicating the direction and the magnitude of the absolute motion of the earth and the solar system in space. If observations were made for the determination of such an absolute motion, what would be the result, independent of any "expected" result? For the purpose of answering this general question, it was decided to make more extended observations and this was done in the months of March, April, July, August and September, 1925.

The observations made at Mount Wilson in 1925 are more than twice as numerous as all the other ether-drift observations made since the year 1887. The total number of observations made at Cleveland represent about one thousand turns of the interferometer, while all the observations made at Mount Wilson previous to 1925 correspond to one thousand two hundred turns. In 1925 observations consist of four thousand turns of the interferometer, in which over one hundred thousand readings were made. This required that the observer should walk, in the dark, in a small circle, for a total distance of one hundred miles, while making the readings.

The ether-drift experiments at Mount Wilson lead to the conclusion that there is a definite displacement of the interference fringes of the interferometer corresponding to a relative motion of the earth and the ether at this observatory of approximately ten kilometers per second. In order to account for these observations as the result of an ether-drift it is necessary to make two assumptions; first, that there is a constant motion of the solar system with a velocity of two hundred kilometers per second or more towards a point in the constellation Draco, near the pole of the ecliptic and having a right ascension of 262° and a declination of +68°; second, that, in effect, the earth drags the ether so that the apparent relative motion at the point of observation is one twentieth of the absolute motion, and that this drag also displaces the apparent azimuth of the motion about 45° to the westward.

The first assumption as to the magnitude and direction of the motion is in general agreement with indications obtained by other methods. The study of the proper motions of the stars and also of the motions in the line of sight lead to the conclusion that the sun is moving towards the constellation Hercules in a direction having a right ascension of 270° and a declination of +33° with a velocity of 19 kilometers per second. Dr. Strömberg finds from a study of star clusters that there is a motion of our cluster in the direction having a

right ascension of 307° and a declination of +56°, the velocity being three hundred kilometers per second. The three determinations of the absolute motion of the system are thus all in the same general direction and lie within a circle having a radius of 26°. The assumed velocity of two hundred kilometers per second is about seven times the orbital velocity of the earth and it is of a reasonable magnitude. This first assumption, therefore, seems to offer no difficulty.

The second assumption that there is a drag of the ether by the earth involves a considerable readjustment of the theories of the ether, inasmuch as it requires a modification of the accepted explanation of aberration. In commenting on the preliminary report of this work presented to the National Academy of Sciences in April, 1925, Dr. L. Silberstein said: "From the point of view of an ether theory, this set of results, as well as all others previously discovered, are easily explicable by means of the Stokes ether concept, as modified by Planck and Lorentz, and discussed by the writer (Silberstein) in the *Philosophical Magazine*."[3]

It has been stated by Eddington that the results of the Mount Wilson ether-drift observations would require star places observed on the mountain and at sea level to differ by 7″ of arc. This statement is based upon the presumption that the ether-drift would have a zero value at sea level. No observations have ever been made at sea level and the indications are that the value of the drift in such a location would be only very slightly less than that observed on Mount Wilson; thus the difference in observed star places would be of the order of one second of arc. Systematic differences in standard star places as determined at different observatories have been noted. The so-called constant of aberration as now universally applied in astronomical calculations does not have a value determined directly from experiment.

[3] February, 1920, Vol. 39, page 161.

All these effects might be explained on the hypothesis of a variation in ether-drift due to differences in the local coefficient of drag. The drag at any given station may be dependent upon altitude, local contour and the distribution of large masses of land such as mountain ranges; the effect may be likened to ordinary refraction, with the interferometer measuring the index of refraction which has a magnitude of the order of 10^{-9}.

The reduction of the indicated velocity of two hundred or more kilometers per second to the observed value of ten kilometers per second may be explained on the theory of the Lorentz-FitzGerald contraction without assuming a drag of the ether. This contraction may or may not depend upon the physical properties of the solid, and it may or may not be exactly proportional to the square of the relative velocities of the earth and the ether. A very slight departure of the contraction from the amount calculated by Lorentz would account for the observed effect. A reexamination of the Morley-Miller experiments of 1902–1904 on the Lorentz-FitzGerald Effect is now being made, with the indication that the interpretation may be modified when taken in connection with the large velocity of the solar system indicated by the observations of 1925. A definitive numerical calculation will require several months of continuous work and is now in progress.

RADIO COMMUNICATION WITH SHORT WAVES

By Commander A. HOYT TAYLOR

SUPERINTENDENT OF THE RADIO DIVISION, NAVAL RESEARCH LABORATORY

THE radio art had its genesis in the experiments of Hertz in Germany in 1885. Hertz used waves of very short length, namely, in the neighborhood of the band from one and a half to three meters. The first radio signals, which could scarcely be called messages, were sent across a room in a physical laboratory. The region in which waves were studied rapidly extended from a few meters to several thousand meters in wavelength.

The experiments of early investigators have been forgotten by many, but within the last three years some very remarkable results have been obtained as the outcome of studies of communications on short waves, which, although not quite as short as those used by Hertz, are nevertheless of the same general order of magnitude. I refer in particular to wavelengths in the band between ten meters and one hundred meters. The early experimenters had neither adequate devices for detecting short waves nor means of producing short waves conveniently with any considerable amount of energy. Indeed, until the invention of the vacuum tube transmitter it would have been utterly impossible by any means known to the art to produce short wave radiation of strength sufficient for experiments at any distance. In the meantime the art had naturally extended itself into the range of longer waves where greater energy could be produced and there were many things to be done in this line of development.

The United States Navy had been using as far back as 1917 or 1918 waves as short as one hundred and fifty meters and sometimes one hundred and twenty-five meters, but only for communication at short distances within the fleet. Aside from this limited use of fairly short waves by the navy, comparatively no use was made in this country of waves shorter than two hundred meters. All waves shorter than two hundred meters were considered worthless for reliable long distance work.

In the early days of amateur radio communication, the amateurs operated on a great variety of wavelengths, but they were restricted when government regulations finally stepped in, in the interest of avoiding interference. Operating in the two hundred meter band, the amateur stations of five to ten years ago established many remarkable long distance transmission records, but it was found upon analysis of these records that very few transmissions were recorded for distances over 150 miles by daylight and that the nocturnal transmissions were extremely erratic and unreliable. Indeed, they were so uncertain that the military and commercial interests of this country were well satisfied that they were not in this wave band. For a number of years no one thought seriously of attempting long-range experiments on still shorter waves because as one studies the behavior of transmissions from fifteen thousand meters down to two hundred meters, it is easy to see that the daylight ranges rapidly decrease and that the night ranges become more and more erratic and unreliable. However, the amateurs of this country made a strenuous and concerted effort to get signals from this country into Europe with low power transmitters operating in the two hundred meter band, but the experiments were attended

only with a very limited amount of success.

Somewhat later experiments were undertaken in the neighborhood of one hundred and five to one hundred and ten meters which showed entirely different results. The experiments by American amateurs are of particular interest because they were carried out, in most cases, with less power in the transmitting antenna than would be required to operate an ordinary electric flatiron and yet several of them were able to put signals into Europe consistently for a good many hours at a time and for many nights in succession. The behavior of these waves in the neighborhood of one hundred meters was a distinct reversal of form and exactly the opposite of what would have been expected by every one familiar with the developments in the longer wavelengths. Instead of signals being of less intensity than those sent out on two hundred meters with the same power, they were of much greater intensity, and instead of being more unreliable they were a great deal more dependable. The success of the American amateur in bridging the Atlantic even if only during the night hours with a ridiculously small amount of power, opened the eyes of the whole world to new possibilities in short-wave communication. From that time on, the development has been extremely rapid, and in this new development the technical staff of the Naval Research Laboratory, located in the southern end of the District of Columbia, has played no inconsiderable part. For more than a year one of the transmitters, built at this laboratory and placed at the disposal of the Navy Department during the night hours, has carried almost the entire night load of our high-powered station at Annapolis which has resulted not only in the saving of a considerable sum of money for the navy, but has relieved broadcast listeners in Baltimore, Washington and Annapolis of the extremely disagreeable radio interference which emanated from the high power, long-wave station at Annapolis.

From the point of view of my listeners one of the greatest advantages of the use of short waves is in the enormous reduction of interference which is to be expected as the new short wave stations are developed and gradually take over work during broadcast hours at least.

The Naval Research Laboratory has just completed an investigation of the conditions of broadcast reception within half a mile of our most powerful transmitter and it has been found that a moderately selective receiver of the type not making use of any oscillating tubes shows no serious amount of interference even if as close as half a mile. The interferences which will occasionally be observed, although they are very rare indeed, from short wave transmitters, generally are not the result of the high frequency transmitters themselves, but are due either to a very non-selective receiver or to a combination of a number of other transmissions from different sources with the short-wave transmission. This sort of combination is not peculiar to high frequencies but can occur in any powerful transmission. Investigations have proceeded far enough to state definitely that the interference from the transmitters used at the Naval Research Laboratory on high frequencies in communicating with the commander-in-chief of the United States fleet during the Australian cruise, and which had no difficulty in putting signals directly into New Zealand and Australia, nine thousand to ten thousand miles, respectively, is not nearly so great an interference by a factor of many times as the interference which would have been experienced from a long-wave transmitter which at best would not have been capable of handling similar traffic much further than the Pacific coast.

A very great change in the nature of the observed effects occurs as the waves are shortened still further, and it would appear from theoretical considerations which have been published in "QST" for October, 1925, and which will be published in the February issue of *The Physical Review,* that waves much shorter than fourteen meters will not be of much use for really long-distance work. Even in the band between twenty and forty meters, a new phenomenon occurs which we call the skip distance effect. It is now definitely known that the wave directly radiated from the antenna and spread out over the ground in the usual manner is very quickly absorbed and is of no use in long distance work. On the other hand, the portion of the rays which radiate up slantwise towards the sky from the antenna are refracted from an ionized region whose height varies from fifty to seven hundred miles according to the time of the year and time of the day, and these rays coming down to earth again after a considerable distance are the ones which are valuable in communication. Under certain conditions, when operating in the band from twenty to forty meters, stations at relatively nearby points—that is, a few hundred miles away—will be skipped over or missed entirely, whereas very intense signals will be received much further on. This effect naturally was very puzzling before it was understood. I can recall an occasion when I was in communication on the twenty meter band with a British station between twelve and one in the afternoon: at the same time, two American amateurs, one in St. Paul, Minnesota, and one in Connecticut, were listening in on the test. The only way I could communicate with the man in Connecticut was to relay a message either through St. Paul or through London. He was unable to hear my signals, and I was unable to hear his. On the other hand, I was perfectly well able to work London. The St. Paul man, on the other hand, being outside the skip distance, which at that time of the year was about five hundred miles for that wave, was able to communicate with everybody. Now during the night hours the skip distance is very great indeed. I have communicated directly with Sydney, Australia, in the twenty meter band without having my signals heard anywhere in the United States outside of the eight or ten miles which would be penetrated by my rapidly absorbed ground wave.

It is a common experience at this time of the year when operating in the forty-meter band, to notice that as the ionized layer of the earth's atmosphere rises to high altitudes after sunset, the skip distance is increased so that the New England stations become gradually weaker as the night hours wear on and disappear at Washington, but at the same time European stations working in this band and our midwest and West coast stations, to say nothing of New Zealand and Australia, come in very well indeed. It is due to the use of the "sky wave" (as it has been termed by Mr. Alexanderson) which passes through a medium not capable of absorbing it, that such immense distances can be covered with such a small amount of power. Communication between the United States and Australia has been maintained on a number of occasions by American amateurs using only a few watts; in other words, much less power than is required to light a twenty-five-watt electric lamp. I do not say that communication was fully reliable with such power, but nevertheless a number of messages have been thus exchanged.

One result of the short-wave development has been the eager entry of amateurs in almost every country of the world into the transmitting game. This brings its troubles and makes necessary very careful government supervision to prevent trespass upon bands allotted to

the government and commercial activities. On the other hand, however, this has given the radio art a tremendous advance and it has permitted the forming of almost countless international acquaintances. It is not at all uncommon these days to listen in on conversations between South Africa and New Zealand, or between Great Britain and America, or between France and South America. I have known an American amateur to communicate with amateurs of three or four different nationalities in one evening. I do not need to tell you that all this is bringing the world closer together and helps people who are geographically far apart to understand each other better, which is one of the best ways to reduce the chance of armed conflicts in the future.

Another very interesting thing has come out of the short-wave development, and that is, that it is entirely possible to receive a radio signal on short waves over greater distance than one half way around the world. Knowing the properties of these waves, we can definitely say, if Johannesburg, South Africa, hears one of our west coast stations at a time of the day when there is nine hours of daylight between that station and Johannesburg, that a forty-meter wave could not possibly have traveled such a distance during daylight, therefore it must have gone the other way around the world, namely, a distance of sixteen thousand miles.

Sometime when the conditions are just right, it should be possible to locate a receiving station within the skip distance of a transmitter operating on very short waves, and to receive a signal from that transmitter after it has traveled completely around the world.

I am the last person to minimize the great value of broadcasting as it exists to-day. Some of you in the old days long before the existence of WCAP or WRC remember the pioneer work done by NSF and NOF, which stations were operated by the navy under my direction and were the first stations in the world to broadcast a presidential speech and various addresses by cabinet members, members of Congress and other officials, and also the first to put on the air the U. S. Navy Band and the U. S. Marine Band. Nevertheless, I believe that the short wave experiments under way these days bringing the peoples of the world so much closer together are of equal importance with broadcasting. They are indeed closely connected with projects of international broadcasting because the link between countries far distant from each other which permits the transfer of foreign programs through our stations is the short wave transmitter.

SOME COLD WAVES OF GEOLOGIC HISTORY

By Dr. DAVID WHITE

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THE climatic abnormalities of 1925 and 1926 will long be remembered; late autumn skating in England and snows and floods in France and sunny Italy; mild weather, suggesting spring, in the Siberian winter, and frightful storms over the North Atlantic; two ocean currents shift their courses slightly, and green fields wave on the west coast of Peru where a desert climate of forty

years between rains is said normally to prevail.

Meanwhile, Dr. C. G. Abbot, of the Smithsonian Institution, insistently reports that for three years, ending last summer, the heat given off by the sun has been 2 per cent. below the average in amount. Some sort of weather upset was bound, he says, to take place somewhere on the face of the earth, but not everywhere. Dr. Abbot does not say where.

After all, however, the cold waves—even the consolidation of all the cold waves and storms of the winter—are insignificant in comparison with the winters of the glacial period. I refer, of course, to what geologists call the Glacial Age of the Pleistocene. This was a period of extraordinary weather, during which, at as many as five different times, great ice sheets, thousands of feet in thickness, spread from the north and northeast over northeastern America, as far south as Kansas, Kentucky and New Jersey. Four such ice caps were developed in northwestern Europe, while Antarctic lands also were more deeply ice-buried than now. In the Sierra Nevada in California, some of the ice tongues, creeping down in the valleys, were over sixty miles in length.

The areas covered by these great ice sheets did not fully coincide, for the earlier ice extended farther to the southwest; but for the most part they overlapped. Over four million square miles of the mainland of this continent was ice-covered.

The glacial period as a whole was almost certainly over six hundred thousand years long, but the interglacial portions, the intervals between the several ice sheets, occupied most of the time, being very much longer than the durations of the ice. During some of the earlier interglacial intervals, one of which was probably two hundred and fifty thousand years long, the climate in the glaciated regions was much warmer than it is to-day.

Before these vast devastating ice invasions took place, with drastic climates extending far beyond the borders of the regions actually covered by the ice, representatives of the rhinoceros, camel, llama, lion, tiger, horse, tapir, mastodon and elephant roamed in different parts of what is now the United States. Also not less than ten kinds of horses were present. Some of these animals survived the first and even the second or third of the great ice invasions, but none of them, except the elephant and the mammoth, seem to have been here when the last—the great Wisconsin ice sheet, which covered all New York, New England, Michigan, Wisconsin and northern Pennsylvania, as well as most of Ohio, Indiana and Illinois—began its retreat. During these prolonged cold waves, musk oxen pastured in Utah, Oklahoma, Arkansas, Ohio and Pennsylvania; the northern or woolly mammoth strayed south of the Potomac River, and walrus sported in the water off the New Jersey coast. The horse, you will remember, has been brought back to America by the white man.

In cave earth, fallen into an old sinkhole near Cumberland, Maryland, during one of the warm interglacial intervals, Dr. Gidley, of the National Museum, found many extinct animals, including a tapir, a crocodile, a peccary and an eland, the latter hardly distinguishable from the eland now living in Africa. This most striking aggregate, including animals no longer living on this continent, is bound to set us thinking about the changes of climate and the intercontinental land connections which made it possible for these creatures to meet together and live near the present southern border of Pennsylvania. A few other discoveries, hardly less remarkable, have been made in other portions of the country, but the wealth

of information regarding the climatic changes and the distribution of animals and plants in this very recent time to be gained by the systematic search of cave deposits is still almost untouched. This fascinating field of investigation, which may yield surprises in the way of human remains also, is greatly neglected in America. It invites attention.

It is remarkable that these great changes in climate and life should have taken place so recently, for geologists tell us that while the first of the ice sheets formed over half a million years ago, the last great ice sheet, the Wisconsin, began its backward thaw only seventeen thousand or perhaps twenty thousand years ago. In fact, if all geologic time were but one day, the events of the last glacial period would all have taken place within the last fifteen or twenty seconds, or while I am saying it.

The Pleistocene glacial period is most interesting to us because it is so realistic and close; because the tracks left by the Wisconsin ice sheet are so conspicuous and have neither decayed nor been covered by deposits of a later epoch, and because the movements of the ice and the fluctuating climates determined to a large extent the composition of the animal and plant life which we now see about us.

However, this period of Pleistocene glaciers and warm interglacial intervals was neither the first nor the greatest of the great ice ages of geological history. Periods of far more sensational climatic phenomena occurred both in early Permian time, which is rather far back, and in that period extremely remote, even from the geologic viewpoint, known as the Laurentian.

Permian glaciation was far more widespread than that of the Pleistocene, and, what is most remarkable, the ice developed in great sheets even within the tropics. Glaciers and, in some cases, ice caps, were present in tropical India, and in eastern South America to within ten degrees of the equator. All Africa south of twenty-two degrees seems to have been buried under ice which reached a thickness of four thousand feet. Icebergs spread thick mantles of glacial débris over the submerged portions of east, west and south Australia.

The Huronian glaciation was vastly more ancient even than the Permian. Ice-planed surfaces or moraines dating from the Huronian have been discovered in Ontario, Scotland, Scandinavia, India, China, Australia and in both equatorial and southern Africa. Measured by the new geological time scale which, as explained to the radio audience last winter by Professor Hess, is based on the rates of atomic disintegration of certain radioactive minerals in the earth, the Permian cold period should date back about seven hundred million years, or a thousand times further than the beginning of the Pleistocene glacial period, but the climatic severities of the Huronian took place probably as much as one billion five hundred million years ago. There were no vertebrates and no trees or other land plants in that ancient epoch.

Evidence of glaciation in some of the intervening geologic periods also is reported. These periods of minor and relatively local cold were the upper Devonian; the lower Carboniferous, when ice-borne boulders were scattered in eastern Oklahoma; and the Eocene, when glacial morainic deposits seem to have been laid down at moderate elevation in Colorado and Wyoming. Most of the vertebrate animals that were exterminated from this continent by the drastic climates of the Pleistocene were in process of evolution in the Eocene.

What were the causes of the periods of widespread cold, with the formation of continental ice sheets, at different regions of the earth? Frankly, we do not yet know. This is another question pressing for answer through research. If the observations by Dr. Abbot are

correct they point toward periods of deficiency in the amount of heat given off by the sun—which appears, in fact, to be a variable star—as possible causes of, or at least as important factors in causing glacial periods. A deficiency of so little as 2 per cent.—the rate of loss endured during the past three years—must produce appreciable results if it should be continued through a long term of years. A 5 to 8-degree Fahrenheit variation from the normal mean temperature distinguishes a very severe or a very mild season. A long-continued departure of 11 to 13 degrees on the side of coldness would probably bring glacial climate to many portions of the earth. Other suggestions proposed by different authorities are magnetic effects, volcanic dust and changes in the composition of the atmosphere. Glacial ice begins to grow where the accumulation of winter's snow and ice is ever so little beyond the thawing capacity of the average summer.

On the other hand, the determination of the climatic results of possible periodic variations in the sun's heat or the other possible causes—*i.e.*, the control of their expression in exaggerated heat or cold in one region or another of the earth and the localization of their concentrated effects—have to do with earth conditions, chiefly the relations, sizes and surface features of the continents and the seas. The essential controlling factors are the stages of emergence—the sizes and the shapes, the elevations, and possibly even the positions of the continents; the positions and relative heights of the mountain chains; the intercontinental connections, which have so often shifted in times past, and the corresponding sizes, shapes and connections of the oceans; the mutual relations between lands and seas; and finally, the densities, temperatures, volumes and velocities of the currents both of the ocean and of the air. These are the factors distributing, and to an extent, regulating the climates of to-day; they determine the regions of arid desert, of heavy rainfall, of fog belts, of dry winters, of maximum heat and of maximum cold; they order that Yuma shall be hotter than Savannah in the same latitude, and that the coldest spot in the northern hemisphere shall be in Yakutsk, Siberia, one thousand eight hundred miles from the north pole, rather than at the pole itself; and that Greenland shall be covered with an ice cap except at the extreme north end, which is cold enough but too dry, while the Pacific Coast climate of Alaska is surprisingly mild. Possibly glaciation on an extensive scale might be induced in some region simply by the coincident cooperation of favoring factors of land and sea.

It is the well-founded belief of oceanographers that weather in America is largely made at sea, in reaction to oceanic currents, as has just been witnessed off the Peruvian coast. It is said that if we had more exact knowledge of the width, depth, routes, velocities and temperatures of the sea currents, and especially of the nature and the results of changes in them, such as must be produced by changes in solar radiation, it would be possible not only better to understand the causes or sources of our atmospheric currents, but also to attain far greater success in weather prediction. When one recalls what stupendous benefits would be realized every year in agriculture, transportation, sea commerce, naval movements, aerial navigation, industry and even in recreation, by a gain of so little as 5 or even 3 per cent. in weather prediction, he wonders why some one does not make the requisite relatively small annual investment, through a term of years, in this field of scientific investigation. In view of the enormous stake, affecting every man, woman and child, and amounting to

colossal figures in dollars, it is remarkable that so little interest is taken in the scientific study of the weather, its causes, its history and the control of its changes.

Perhaps you say that ice caps still cover Greenland and Antarctica; that glaciers still survive in mountain regions; that present-day climate is abnormal and marked by extremes (which is true); and that if the time since the Wisconsin ice sheet thawed back is less than twenty thousand years, a mere fraction of the long intervals between some of the Pleistocene ice sheets, how shall we know that the glacial age is really past? May not another great ice sheet spread over northeastern America, burying the face of nature, especially if we should have a long period of deficiency of the sun's heat, combined with favoring continental and sea conditions? Really, no one knows the answer to this question. Lands and seas are ever changing; but some, at least, of the terrestrial climatic factors, such as changes in the shore lines and mountain elevations, now in progress point rather distinctly in the opposite direction. It seems probable that only some reversals of movement, which I have not now time to discuss, possibly combined with other causes, such as marked deficiency of solar radiation, could, in the course of a long time, bring on another great ice sheet.

PROGRESS AND PROPERTY

By EZRA BOWEN

LAFAYETTE COLLEGE

OLDER than incorporation, older than marriage, older than contract, older than religion—property is man's oldest institution: the right to use and enjoy to the exclusion of others is an expression of the instinct of self-preservation, and therefore as old as life itself.

"Primitive communism" is a myth. Overwhelming evidence points to its antithesis, primitive individualism, with an intense and violent sense of property —an instinct that antedates the appearance of man.[1] Caribou graze contentedly together, but only when there is wide pasture of so nearly equal quality that no part is worth claiming. Several hippopotami may bathe peaceably in one stream, but let that stream dry up, only a small pool remaining, and you will see in it one huge hippopotamus, enjoying exclusive bathing privileges. Finally, who will dispute the completeness of the property right of she-bear in her cave?

Social scientists have long held an opposite view, maintaining that "Everything was at first held in common,"[2] or "In the early stages of society the concept of private property is absent."[3] This view of private property would be correct were the pack stage of human development or the fortress-village stage really primitive, for in these two isolated and by no means primitive instances, some—though far from all—property was communized. But these two fear-engendered kinds of huddling are no more important in the evolution of human usage than are the whale and bat instances in the general biologic flow. The driving of one whole species of mammals into the mother waters and of another into that exclusively reptilian domain, the air, may be considered—are considered—purely sportive back-eddies in the widening flow of kinds.

Objects of primitive property were few, but it is a mistake to say "The concept of private property is absent"[4]— or even slightly developed. It is a mistake to say that the stone axe of a primitive chieftain, the only stone axe for miles around, was less of property, or even less property than a modern steamship. Property is a subjective matter.[5] Objectively, property was indeed inconsiderable in primitive times; but subjectively it was far more important than to-day. So sharp and clear was the concept of property that much (if not all) of man's belongings were buried with his body. That this nearly universal custom of primitive peoples was purely altruistic, that it came solely from a desire to provide the departed with equipment for a life to come, is a one-eyed view, a view that lacks perspective. More in accord with collateral facts is the explanation that a man's scant possessions were buried with him because

[1] C. Letourneau, "Property, Its Origin and Development," 1901.

[2] *Op. cit.*

[3] E. R. A. Seligman, "Principles of Economics," 1924. (The *law* of property was perhaps absent—unless common law in its nebular form, common usage, is meant—but the *concept* of private property was anything but absent.)

[4] *Loc. cit.*

[5] For may not any property relationship be altered, or even destroyed, without the slightest alteration or destruction of object or objective attribute? The war amendments to the American Constitution destroyed no black men, but they wiped out completely property in human beings.

they were *his*—so completely of him that they might possibly work a subsequent user harm. When Mr. Robert Dollar dies, his steamships will not be buried with him, nor any of his belongings; the concept of property has been sharply whittled down.

Property, then, was not built up to its present height from zero. On the contrary, its present level was reached by constant falling—and still it sinks.

Evolutionists find an additional hoop for their barrel in embryology; anthropologists and social-psychologists see one in the apparent connection between the mental history of mankind and that of a present-day pre-adult. Our theory of a direct relationship between the growth of civilization (and intelligence) and the expunging of the harder lines of private property finds similar reinforcement: A very small boy has a sense of property that is not soft. It is bounded by straight hard lines and the corners are very sharp. Sister may not have his drum—not even for a little while. She may not beat it, not even if she lets him hold it. May she tap it just once? No! An older boy owns a baseball, a bat and a glove. The boy next door wants the bat—not the ball and glove—just the bat. No, he may not have the bat. The neighbor's boy pleads for the ball. No, he may not have the ball. Well, then, just the glove? Again, no! With age and experience this propertied young man learns that he can profit by conceding some of his rights. And this whittling down of his concept of property progresses with years.

With the inception of intelligence and ability to measure sacrifice against corresponding gain, the institution of private property begins to lose its pinnacles and corners. And with every age and year, it wears smoother, rounder, smaller.

The past one hundred years have brought an onrush of civilization; the concept of private property has shrunk proportionately. The division of labor, that most fundamental and almost universal influence in social evolution, is an insatiable solvent of property. The inescapable concomitants of any division of task are cooperation and coordination: before them, exclusive rights of use and enjoyment have by necessity given away.

Escheat, the taxing power, eminent domain, the police power—especially the last three—are sledges that have struck away whole slabs of the Gibraltar of private property, making incessant and increasing inroads.

A farm, let us say, has been in your family for many generations. Over the week-end, you may have your friends for a clay-pigeon shoot, but not a live-bird shoot, though your father might. You may have a race-course on the place; you may not, however, set up betting booths, though your grandfather had that right. If a member of your family dies, you may not bury him on the place, but your great-grandfather might. If you raise rye, you may not build a still to make your rye into whiskey, though your great-great-grandfather had this right. These are rural examples of amended rights of use and enjoyment in land—all made under one power, the police or general-welfare power. But it is in urban property rights that this power has wrought its greatest havoc; and everywhere the powers of taxation and eminent domain have made even larger inroads.

You own a city lot, and you decide to put up a frame building on it. No, you may not; the law forbids because it would increase the fire hazard of your neighbors. Well, then, it will be of brick, a loft building. No; loft buildings are not permitted in that section of the city. Then you will build an apartment house, eighteen stories high. No;

buildings of more than six stories are forbidden in that zone!

In the same city you own a large section of water front, all on deep water; you own and operate many docks and piers; but they are not adequate to the needs of the city. The Board of Trade tells you that the city's life depends upon adequate port facilities, and urges you to furnish them. No, the docks and piers you have now do not pay—you will not build more. The next chapter is a sad one. The power of eminent domain is raised, a titanic lever. You and your property are pried apart. The city takes the property, and you a "fair consideration." Never will that water front again be private property.

Property is a right. As old as life, it is however wholly conventional—an artifice, an arrangement. Its purpose, its meaning, its end is to stimulate social, especially economic, activity. Where other motives, the desire to serve, the desire to emerge, the desire for activity itself—where these and other incentives work better, private property has been and will be further modified. Where the growing complexity and activity of society demand a more flexible arrangement, there too property has been and will be further modified.

You own property. Your rights in that property are less than those your father had in like objects; his rights were less than those of his father. Your son's rights will, in turn, be less than yours. Private property, the oldest and, at first, the most uncompromising of social institutions, tends to diminish in force and in scope with the growth of civilization.

THE MALE SEA DEVIL AND HIS WAYS

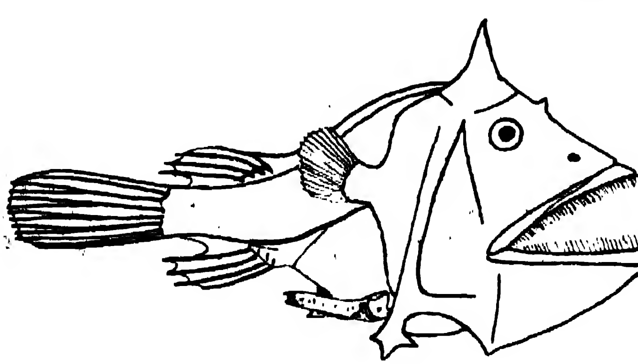
By Dr. DAVID STARR JORDAN
STANFORD UNIVERSITY

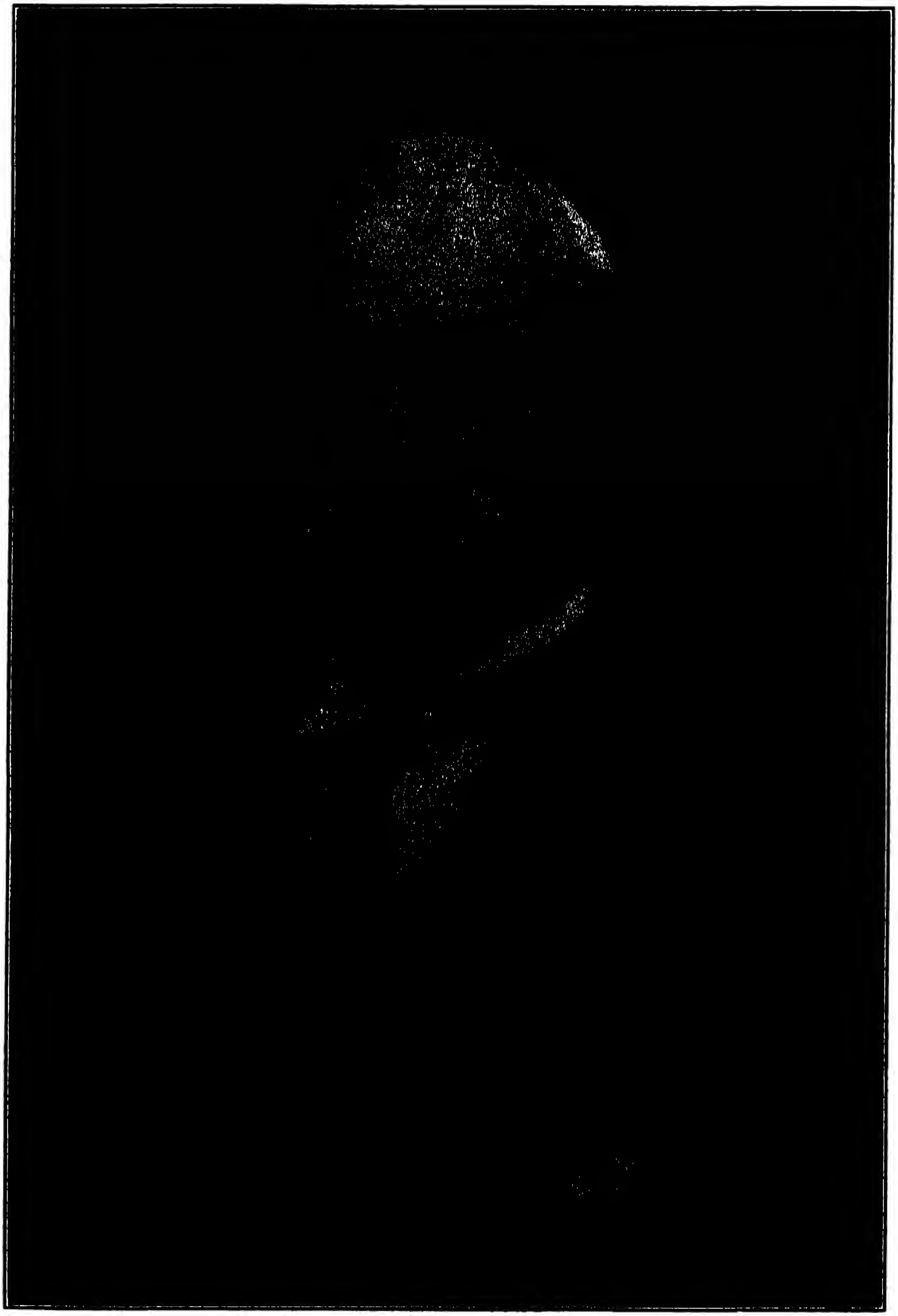
In a recent magazine, I gave an account of the capture of a very rare fish of the type known as Sea Devils, inhabiting great depths (2,500 to 6,000 feet) in the North Atlantic Ocean. Concerning this particular capture there were two very remarkable features, the one the fish itself, the other that the press account of it was absolutely correct. This particular Sea Devil is known as *Himantolophus grœnlandicus* and, like most of its associated devils, the first dorsal spine is separated, turned forwards over the mouth and provided with a luminous bulb at tip surrounded by fringes and which serves as a fish lure.

Some nineteen different types of sea devils (*Ceratiidæ* and *Himantolophidæ*) have been known, most of them from a few or sometimes but one specimen. All the examples hitherto known have been females more or less fully grown, no young having ever been seen, and until very lately no males. These fishes are "wide-ranging, solitary and sluggish, floating about in the darkness of the middle depths of the ocean."

Recently there have been received by the British Museum certain specimens which explain the absence of males. One of these was taken near Iceland, the others off Panama. All these have been described in detail by Mr. C. Tate Regan, of the British Museum. In all three of these, the male fish is a very small creature indeed, about one thirtieth of the weight of the female, and little more than one fourth as long. He exists, in fact, as a parasite on the female, being attached to some soft place, where he draws up the skin into a sort of nipple. The skin of the snout is continuous with that of the female, and no one can tell where one fish leaves off and the other begins. The dorsal angling pole is lost in the male because in his sheltered condition he has no use for bait. The mouth, when retained at all, is used only for breathing. In the particular species represented in the cut, the little male fish hangs on belly upward.

This sort of sex-parasitism is not known in any group of fishes except these devils of the deep sea. Among the higher vertebrates, the only condition analogous is that of a continental duke or count, little, withered and shop-worn, attached to a Chicago heiress.





CHARLES FREDERICK CHANDLER

THE PROGRESS OF SCIENCE

CHARLES FREDERICK CHANDLER

By Ellwood Kendrick

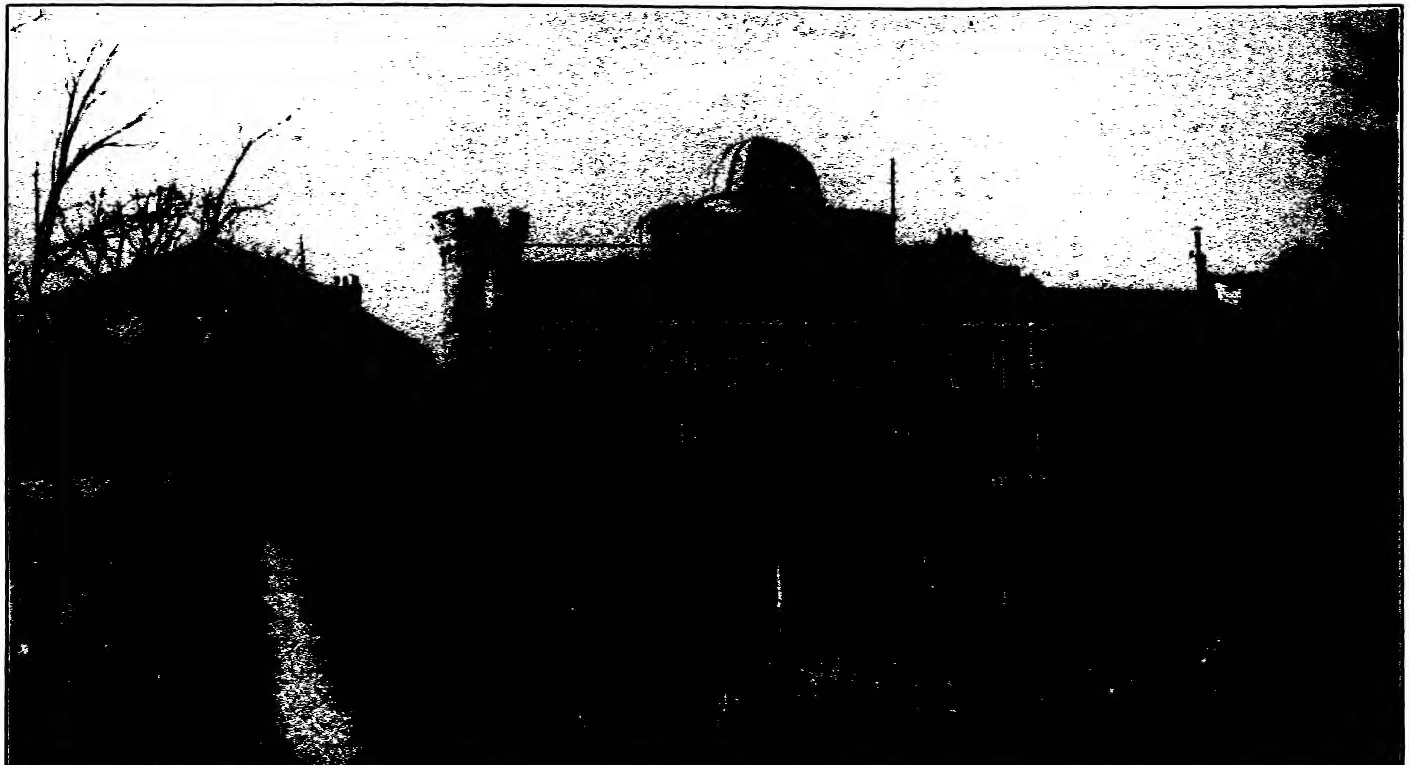
Chandler Memorial Museum, Columbia University

Professor Chandler, who died on August twenty-fifth last in his eighty-ninth year, was an outstanding figure in chemistry in America. He spent his boyhood with his parents in New Bedford, where his father was a merchant. He attended school in his home town, and matriculated at Lawrence Scientific School of Harvard College. While there he met Professor Charles A. Joy, who held the chair of chemistry at Union College, and on his advice, in 1855, proceeded to Göttingen to study with Friederich Woehler, who took him on as his private assistant. From Göttingen he journeyed to Berlin to develop himself in analysis with Heinrich Rose, then returned to make his doctorate in philosophy under Woehler and straightway thereafter came back home at the age of twenty.

He was well equipped for the scientific life. As a boy of fourteen he showed the lively curiosity about chemistry which he retained throughout his days, and he carried on experiments in his own little laboratory in the attic of his father's house. He was greatly impressed by the public lectures of Louis Agassiz which he attended whenever the opportunity offered. He had an amazing capacity for work and he was naturally and congenitally honest.

Chandler was remarkably practical, a quality that probably gave him his slant towards industrial chemistry rather than in the direction of research in pure science. His constant effort was to bring chemistry into use, and he gave slight thought to his own advantage or profit in the matter.

On returning to New Bedford from Germany he found a situation that has grown to be familiar to many men of science; a vast amount of work to be done, but nobody aware of the fact except himself. The gatherers and merchants of whale oil could not see that chemistry had to do with their business. So, learning that his old friend Professor Joy at Union College needed an assistant, he posted off to Schenectady only to discover that the sole position for which funds had been provided by the trustees—and this despite Professor Joy's urgent need—was that of janitor at $500 a year! Chandler took the job, and proceeded to teach chemistry and mineralogy and geology as accessory to sweeping up and cleaning. Within a few months, however, in April, 1857, he succeeded Professor Joy to the chair of chemistry at Union when the latter was called to Columbia College. Young Chandler was twenty-one years of age at the time. In 1864 he came to the Columbia School of Mines and was actively associated with that college and university as a great teacher for fifty-six years, and fifteen more as professor emeritus, making in all the well-nigh unprecedented record of sixty-one years of service. His emolument at first was meager, none the less he gave his work without pay to the study of sanitary problems for the New York Board of Health, to teaching chemistry in the College of Physicians and Surgeons and to the students of the College of Pharmacy. In time he became president of the Board of Health, president of the College of Pharmacy and professor of chemistry



THE FLAMMARION OBSERVATORY AT JUVISY

Here the well-known French astronomer did most of his work and died recently. The observatory occupies an old house which was a favorite stopping place for the kings of France on their way to and from Fontainebleau. It was in this house that Napoleon signed his abdication on the flight from Fontainebleau and the historic table used is one of the prized possessions of the observatory. A movement is on foot among American admirers of the noted scientist to buy and endow the observatory as a permanent Flammarion memorial. This movement is headed by William McAfee, an amateur astronomer of New York and Paris, who is in France at the moment for the purpose of examining the feasibility of his plan.

MME. GABRIELLE CAMILLE FLAMMARION

WIDOW OF THE NOTED FRENCH ASTRONOMER. SHE WAS HIS SECRETARY AND COLLABORATOR FROM THE TIME SHE WAS EIGHTEEN YEARS OLD, MARRYING THE NOTED FRENCH SCIENTIST SHORTLY BEFORE HIS DEATH. SHE IS NOW ENGAGED IN PREPARING FOR PUBLICATION SEVERAL OF HIS POSTHUMOUS WORKS.

and of medical jurisprudence at the medical school.

He was a pioneer in sanitation and in raising the standards of pharmacy and of medicine. For a number of years he worked from six to eight o'clock in the mornings in the laboratory of a sugar refining company to eke out his income in order to be able to give more time to the public service. He taught chemistry and taught it well, to some 35,000 students. His lectures were eagerly attended. He did not take out many patents, but gave inventions such as the anti-siphoning device and flush-closet in plumbing to the public. Evidences of his scientific acumen and ingenuity may be found in nearly every industry that engaged him. This explains why the list of his contributions to pure science is not large. He was always intent on putting science to use.

He was president of the State Charities Aid Association for several years, chemical adviser to the U. S. Navy De-

HERMANN VON HELMHOLTZ
From the portrait painted by Franz von Lenbach in 1894.

partment, president of the Street Cleaning Improvement Society which organized the better care of streets, chemist to the Croton Aqueduct Commission, a founder of the American Chemical Society—indeed the list of his many activities would fill pages. He was decorated with honorary doctorates by various American universities and by Oxford. He was a great teacher, a splendid citizen and the pioneer of chemical technology in America.

HERMANN VON HELMHOLTZ AND HIS WORK IN PHYSIOLOGICAL OPTICS

By Dr. Charles Sheard

Mayo Clinic and Mayo Foundation for Medical Education and Research

Monuments are constantly being built to the memory of men and women who have served for the common good and the betterment of mankind. Some of those who are thus honored and revered have been great in war and the stalwart champions of the oppressed, and others, for one reason or another, have been "first in the hearts of their countrymen"; some have been captains of industry, while others have thought not of the loom and the ploughshare, but have labored that man might have the treasure which neither moth nor rust doth corrupt, nor thieves break through and steal. Such men and women have been acclaimed in large measure, first of all, by their own peoples, to be later venerated as citizens of the world. So the scientific world, endeavoring to "prove all things and to hold fast that which is good," has long since acclaimed von Helmholtz as one of the first citizens of the world of fact and truth, and has built to his memory a monument out of the materials which he provided.

The nineteenth century will always be famous for the enunciation of two great generalizations on which all science rests. The twentieth century, with all its marvelous advancement, has not overshadowed these discoveries and their importance nor can it, perchance, point to such a galaxy of names as those of Darwin, Wallace, Maxwell, Pasteur, Kelvin, Joule, Helmholtz and others. And it is to these last three—Helmholtz, Joule and Thomson (Lord Kelvin)—that the world is indebted "for the most important and far-reaching generalization in physical science since the time of Newton," for at the age of twenty-six years Helmholtz produced his paper on the "Conservation of Energy" which constitutes, perchance, the most important piece of work in his career of half a century as an investigator.

At the age of thirty, in the year 1851, Helmholtz invented the ophthalmoscope. When the famous ophthalmologist von Graefe was shown the instrument and saw for the first time the fundus of the living human eye, with its optic disc and its blood vessels, he is said to have exclaimed: "Helmholtz has unfolded to us a new world." It is claimed by some that the credit for the first ophthalmoscope should go to Babbage, an English mathematician, who, in 1847, exhibited to Wharton Jones, the distinguished London oculist, the model of an instrument invented by him for examining the interior of the eye. This device, however, was not made known to the world by Jones until 1854. At any rate, the independence of the workers and the self-sufficiency of the labors of each of these men—resulting in the invention of one of the most marvelous and useful instruments for observation and diagnosis in the field of medicine—may warrant the linking toegther of the names of Helmholtz and Babbage. For there is glory enough for both.

In 1855 Helmholtz became professor of anatomy and physiology at Bonn and

four years later accepted a like professorship at the University of Heidelberg, where he remained for a dozen years. During these years (1855–66) he wrote his great treatise on *Physiological Optics,* which appeared in three parts. This treatise is, without question, the most important book on the physiology, psychology and physics of vision which has ever been penned. In 1862 he published his work on *Sensations of Tone,* which may well be termed the principia of physiological acoustics.

Helmholtz's earliest work in physiological optics dealt with the refractive apparatus of the eye and to this he brought the exactness of training and the viewpoint of a physicist and the desire to understand and interpret the functions of the eye and the ultimate nature of the visual mechanism in terms of general optical theory. By means of the ophthalmometer and the phakoscope, which he invented, Helmholtz obtained many data on the eye as an optical instrument, as well as on the accommodative mechanism. Possibly the theory of accommodation as laid down by Helmholtz may not stand the test of time, but it is to be questioned whether any equally satisfactory alternative explanation has as yet appeared. His skill as an anatomist and his knowledge of general optical science made all these things possible and enabled him to pioneer in the catoptrics and dioptrics of the human eye.

Helmholtz's interest in the ultimate mechanism of the visual function led him to advocate a definite hypothesis as to the physiological processes or operations underlying color vision. Perhaps the theory should be called the Young-Helmholtz-Maxwell theory. Helmholtz gave the hypothesis of Young a definite "standing in court" in terms of established principles. Of course, he did not prove his color hypothesis and raise it from the realm of a guess to that of a fact; neither, in the best judgment of those competent, has anybody else proved another conception in the matter of color vision. Besides his color hypothesis, Helmholtz developed the color triangle to a point beyond that to which it had previously been carried and made clear the difference between additive and subtractive mixtures of colors.

Problems of binocular vision and the theory of space perception occupied Helmholtz's attention. He demonstrated that, in his own eyes, the retinal horizontals are parallel to the true horizon, while the apparent verticals are inclined to one another at an angle of about two to three degrees. The interpretation of these observations and phenomena, as well as the universality of their existence, are still much discussed and are open to further proof. On the basis of his data Helmholtz recalculated the form of the horopter, which is the locus of points that fall on corresponding retinal points in binocular vision. His power as a mathematical physicist enabled him to analyze with great accuracy ocular movements and to show that the complicated adjustments of the two eyes are all governed and controlled by the fundamental principle that all objects shall be seen singly so far as such is possible.

At Rochester, New York, October 25, 1921, the Optical Society of America held a Helmholtz memorial meeting, being the observance of the hundredth anniversary of his brithday, at which addresses were made by Professors Southall, of Columbia, Crew, of Northwestern, Pupin, of Columbia, and Dr. Troland, of Harvard. Following this meeting, ways and means were provided for preparing and publishing an English translation of the *Physiologischen Optik* so that there might become available to the English reading world "that great Bible of physiological optics which Helmholtz so painstakingly prepared for us." Dr. James P. C. Southall, a pro-

fessor of physics at Columbia University, was selected as editor-in-chief. The first volume of the translation appeared in 1924, the second during the past year and the third volume, completing this worth-while labor of love, came out in January of this year.

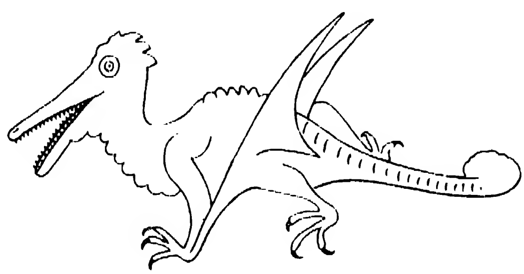
Of the *Treatise on Physiological Optics*, we know of no statement which more clearly expresses the truth than that by Professor Southall, as he writes in the preface to the English translation: "Apart from its own intrinsic value, the treatise on *Physiological Optics* is a model of scientific method and logical procedure that has hardly ever been excelled in these respects."

Of von Helmholtz himself, no finer or truer tribute was ever penned than by London *Punch* in a brief stanza which appeared shortly after the announcement of his death:

What matters titles, Helmholtz is a name
That challenges alone the award of fame.
When emperors, kings, pretenders, shadows all,
Leave not a dust trace on our whirling ball
Thy work, O grave-eyed searcher, shall endure
Unmarred by faction, from low passion pure.

ADDRESS TO THE RHAMPHORHYNCHUS

BY W. A. SPALDING
Los Angeles, Cal.



Preposterous Pterodactyl, looming large
  In scientific thought and speculation,
What was thy province on the early marge
  Of animal creation?

With form outlandish and out-sea-ish too,
  (The merest contemplation makes one shudder),—
A tail extending almost out of view,
  And ending in a rudder;

A monster lizard, Brobdignagian bird,
  Reptile and fish, with every ghastly feature,
A crocodile with wings,—a most absurd,
  A most unsightly creature.

If physiognomy be any guide,
  (It seldom leads us into grievous errors),
You were the oger of the whole world wide,
  The holiest of terrors.

And when you issued from the troubled sea
  Upon the stricken land, or over,
All monsters of a less acute degree
  Began to hunt for cover.

Smilodon smiled, and left instanter;
Hadrosaurus went with a lope and a canter;
Cinnolisaur's coils began to unlimber;
Megalosaurus struck for the tall, tall timber;
Teratornis flew, with squawk and a flutter,
Iguanadon's hops were too utterly utter;
Laelaps leaped wildly o'er bushes and stubble;
Elasmosaur wiggled away from the trouble;
Dinosaurus dove for the muddy bottom;—
And if any remained, Rhamphorhynchus, you *got* 'm.

But the primitive world was a world of change;
  The orders were then what the present command is;
Exuberant life means a limited range;—
  You succumbed to *Mutatis Mutandis.*

And so, Pterodactyl fierce and great,
  This history must be related:
Your license was revoked by Fate,
  Your rights were sequestrated.

It was long ago,—so long indeed
  We scarce can comprehend the distance;—
Some buried strata bear the screed
  Of your condign existence.

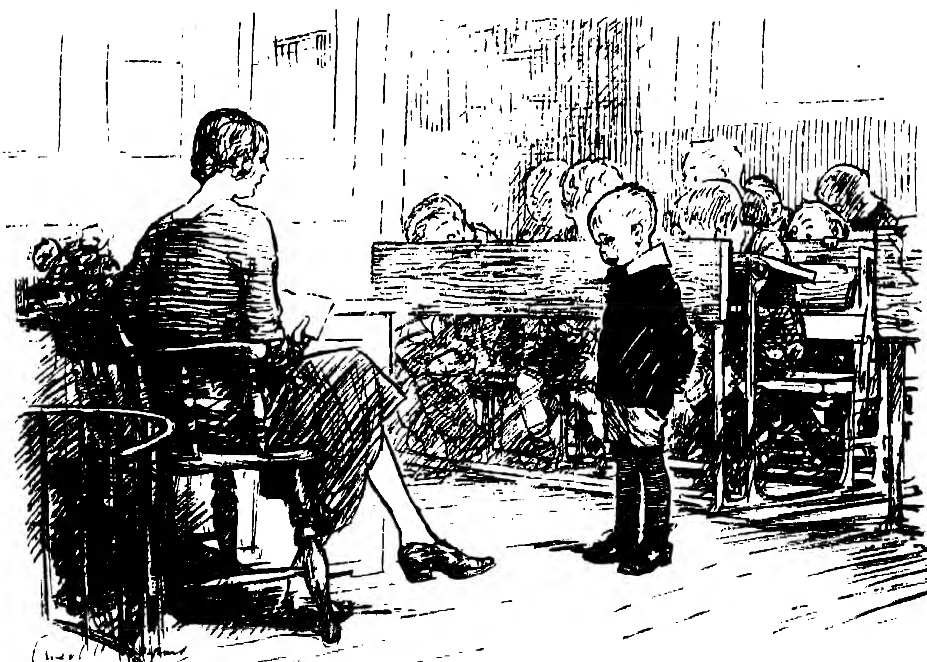
Suggestions of your form and size,—
  Some aspect of your manners,
Are still displayed before our eyes
  On gorgeous Chinese banners;

And frazzled fragments of your frame,
  Trussed up in some museum,
Bear testimony of your name
  To those who go and see 'em.

If, in this tale I could descry
  Some slightly moral notion,
'Twould be, old boy, you aimed too high
  For earth and air and ocean.

And so, to cap your many frills,
  To climax your ambition,
You went to smash with motor ills,
  And burned out your ignition.

WHERE IS THE TOOTHACHE?



Teacher "WHY WEREN'T YOU AT SCHOOL YESTERDAY, TOMMY?"
Tommy. "PLEASE, TEACHER, I HAD THE TOOTHACHE."
Teacher. "I SEE. AND IS THE TOOTH ACHING STILL?"
Tommy. "I DUNNO, TEACHER. DENTIST 'S GOT IT."

—*From Punch.*

THE SCIENTIFIC MONTHLY

MAY, 1926

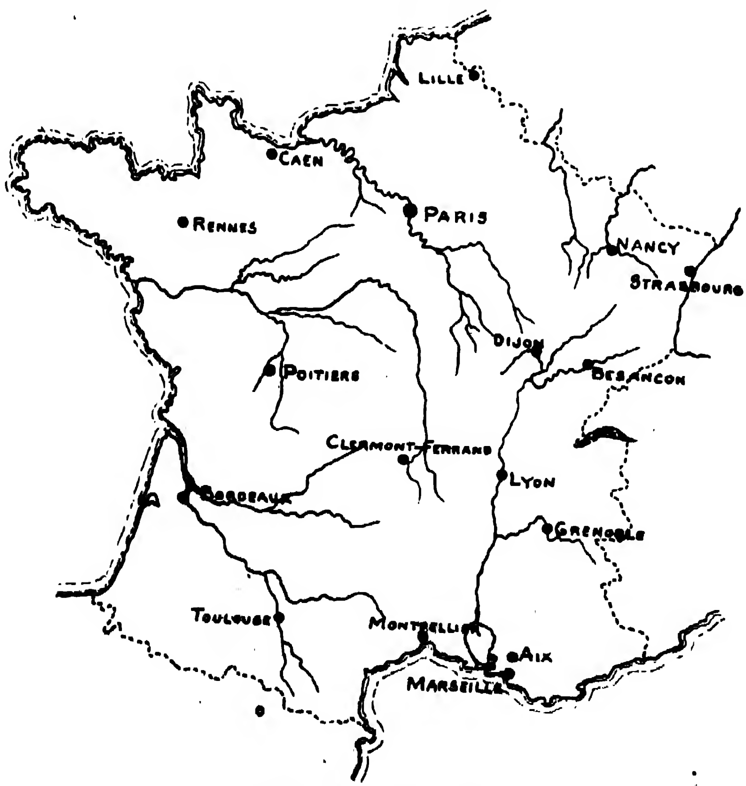
APPLIED SCIENCE IN THE PROVINCIAL UNIVERSITIES OF FRANCE

By Professor E. M. CHAMOT

CORNELL UNIVERSITY

DURING the academic year 1924–25 it was the writer's rare privilege to represent, as fourth exchange professor, the seven large universities of the eastern United States[1] that are in exchange with France of professors of engineering and applied science. His mission, in addition to lecturing at the French universities to which he was assigned by the Office Nationale des Écoles et Universités Françaises, was to meet and become acquainted with his colleagues in France and to obtain as much information as

[1] Columbia, Cornell, Harvard, Massachusetts Institute of Technology, Johns Hopkins, Pennsylvania, Yale.

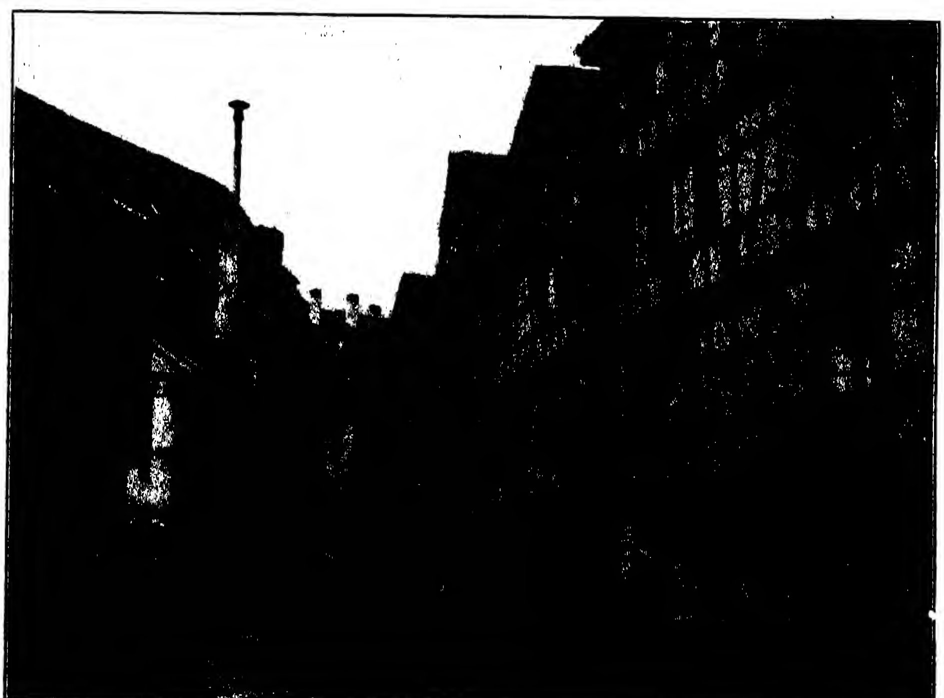


OUTLINE MAP OF FRANCE
SHOWING THE SITUATION OF THE SIXTEEN FRENCH UNIVERSITIES.

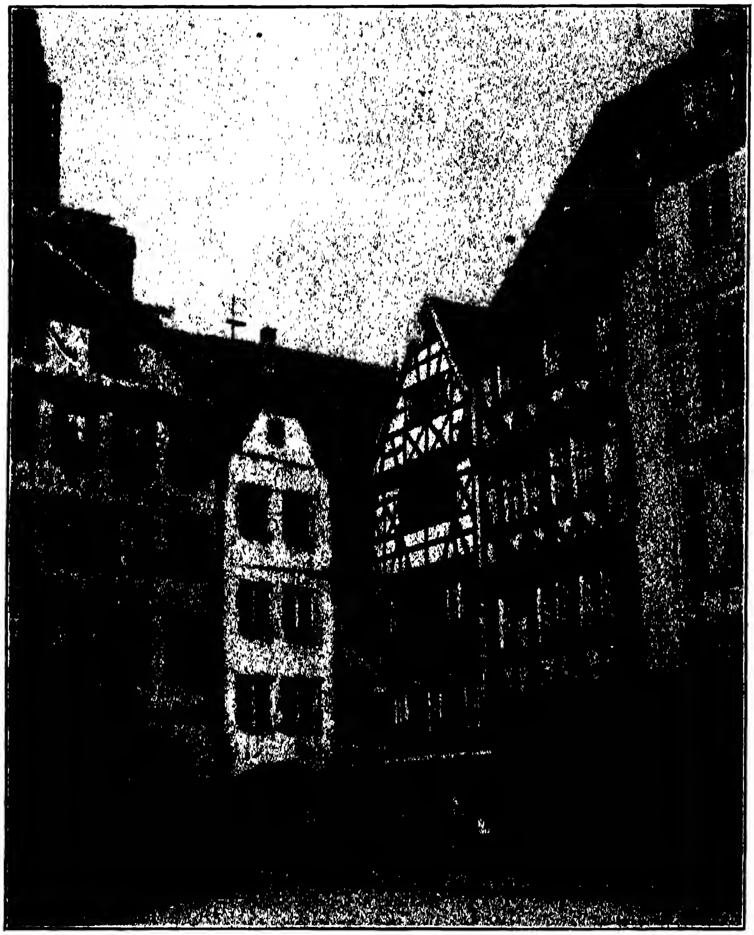
UNIVERSITY OF STRASBOURG, FACULTY OF LETTERS

Immediately in front of the entrance will be seen the monument to the memory of Pasteur. This monument consists of a central obelisk of yellow sand-stone with most curious hieroglyphic-like images, Egyptian in character.

UNIVERSITY OF STRASBOURG, INSTITUTE OF CHEMISTRY



ONE OF THE OLDEST STREETS IN STRASBOURG WITH ITS ANCIENT TIMBER HOUSES

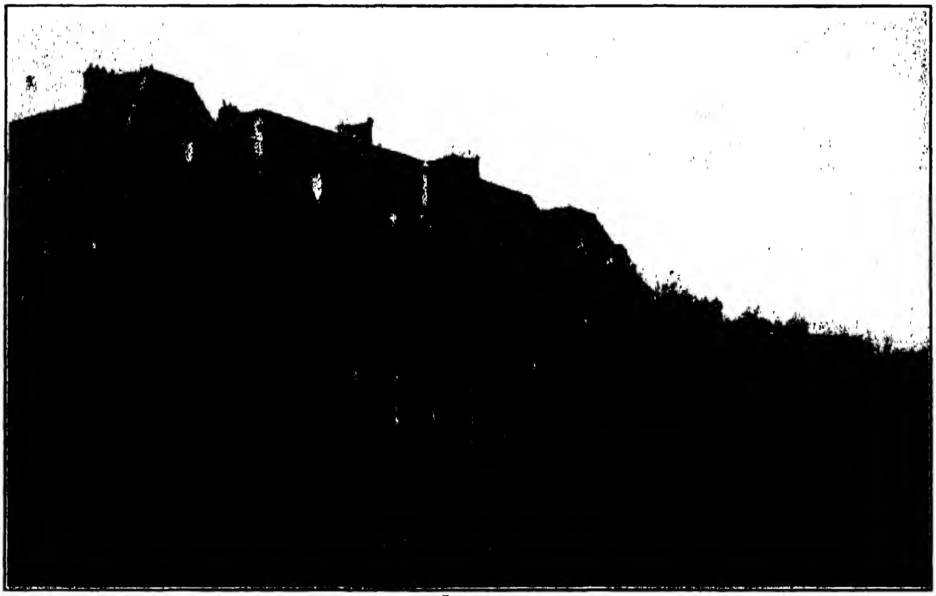


ONE OF THE PICTURESQUE LITTLE SQUARES IN OLD STRASBOURG

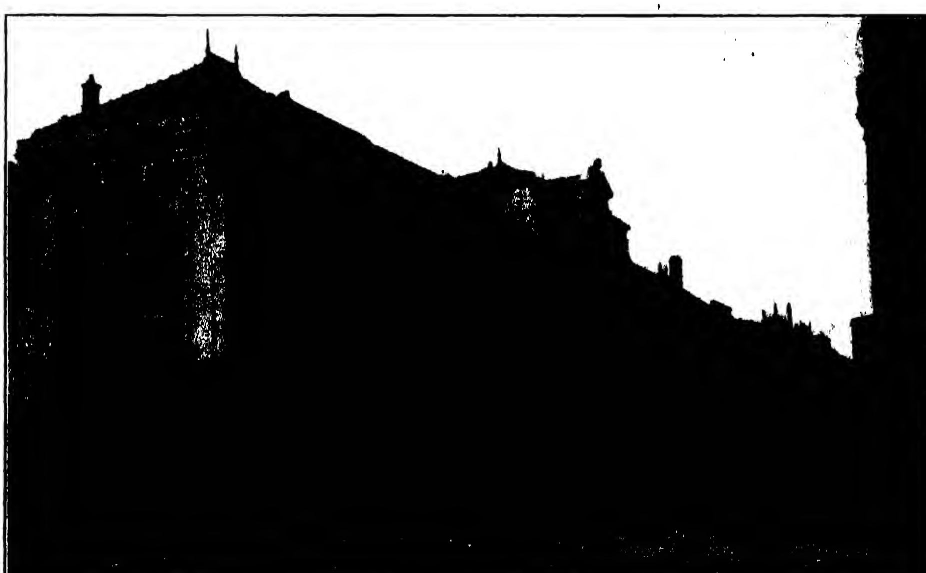
possible that might be of benefit to American students contemplating a sojourn in France either for study or research.

When, therefore, it was suggested by the editors of THE SCIENTIFIC MONTHLY that a summary of the writer's impressions relative to technical education in France would probably prove of interest to the readers of the magazine, the opportunity was gladly welcomed of bringing before American students the character of facilities for study in the universities of our sister republic and especially the opportunities for research in chemistry.

In order to comprehend the educational system of France it must be remembered that we have to deal with a remarkably centralized system with its headquarters in Paris, and further, that politically, educationally, and one is almost tempted to say commercially, France may be regarded as divided into two parts, Paris and the Provinces. By the "Provinces" is meant all that part of France lying outside of Paris and its suburbs. We have thus in common use the terms: the "university and schools of Paris" and the "provincial schools and universities." If we take the view of some of the citizens of the republic



UNIVERSITY OF NANCY, FACULTY OF LETTERS
THE NEW SCHOOL OF METALLURGY AND MINING OCCUPIES THE BUILDINGS AT THE RIGHT OF THE PHOTOGRAPH



UNIVERSITY OF NANCY, INSTITUTE OF CHEMISTRY
THE SCHOOL OF BREWING IS SITUATED WITHIN THE COURT AND THE SOLVAY FOUNDATION OF MECHANIC ARTS STANDS JUST AT THE BACK.

NANCY, PORTE DE LA CRAFFE

ONE OF THE MOST PICTURESQUE OF THE SEVEN CITY "GATES." THIS FINE EXAMPLE OF A FORTIFIED GATEWAY INTO A CITY DATES FROM THE EARLY PART OF THE FIFTEENTH CENTURY. THE TECHNICAL SCHOOLS OF THE UNIVERSITY ARE SITUATED NEAR THIS OLD GATE.

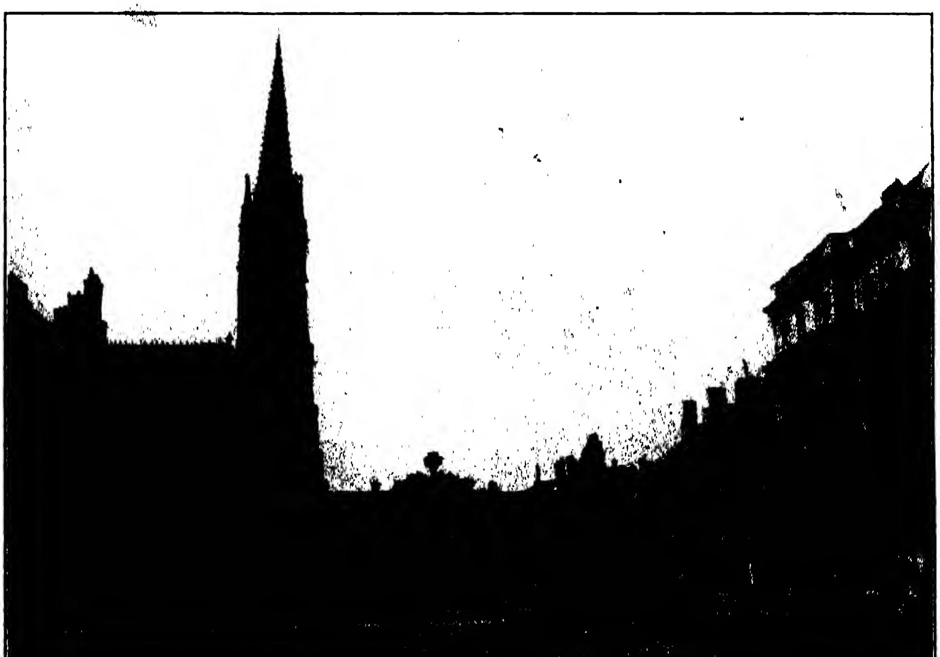
living in the "Provinces"—we are apt to say to ourselves "France is inhabited by Parisians and Frenchmen." It must be admitted that there still exists at least a very little of the old snobbish attitude of superiority on the part of the Parisian, an attitude which the "provincial" resents. More than once in talking over things political and otherwise with chance acquaintances made in my travels in France I have been stopped with—"Attendez—you heard that in Paris, n'est ce pas—Eh bien! How long is it going to take you to realize that whoever told you such things is a Parisian—with a cosmopolitan point of view?"

The official terms "En Province" and "Les Universités Provincialles" are never of course applied in any disparaging sense, yet nevertheless, by tradition, Paris and things Parisian are still apt to be placed upon a pedestal just a tiny bit higher than people and things "en province." And our American tourists, do they say that they are going to France? Almost never! What they shout from the house-tops is "Oh! we're going to Paris!" Even our science students contemplating study in France rarely stop and consider whether they would not do better in their chosen field in one of the provincial universities. Tradition warps

their judgment. It is the aim of the writer to try and make clear the nature and character of the developments in specialized instruction in the provincial universities which render them preeminent, each one in certain branches of applied science.

Tradition has been responsible for the very natural drift to Paris of the great men of France, and Paris has ever been on the watch to call to her halls men who were distinguishing themselves in the other universities and institutions for higher education. A call to the University of Paris meant the culminating achievement of a man's career. He "had arrived," as the saying goes in France. His abilities had been recognized and his work crowned with honor. It will be noted that the writer has used the expression "it had come about," for today somewhat different conditions obtain. One finds great men of science of international fame content to remain "en province" in laboratories which they have built up and which, in many cases, are far superior to those to which they had been called in Paris. Moreover, not a few have had the conviction that they could carry on their investigations with less interruption "en province" than in Paris.

But enough has been said to indicate that educational France has been governed by a most interesting and intricate centralized system based partly upon tradition and partly upon expediency and built up because of the dominating effect of Paris upon matters social and political, a discussion of which would take us far afield. In recent years there seems to have been a movement to grant greater and greater autonomy to the various universities or perhaps it might be safe to say that the universities have insisted upon their rights to admin-



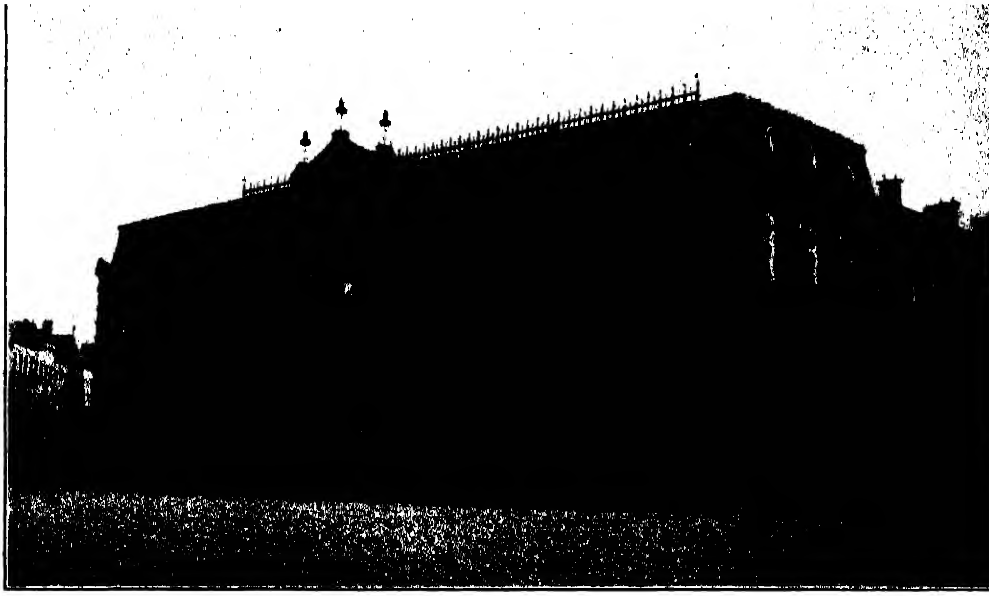
NANCY, LE HEMICYCLE DU GOUVERNEMENT
ONE OF THE ATTRACTIVE SQUARES FOR WHICH NANCY IS FAMOUS.

MONUMENT TO THE MEMORY OF PASTEUR AT LILLE
THIS IS ONE OF THE MOST PLEASING OF THE MANY MEMORIALS TO THIS GREAT INVESTIGATOR IN FRANCE.

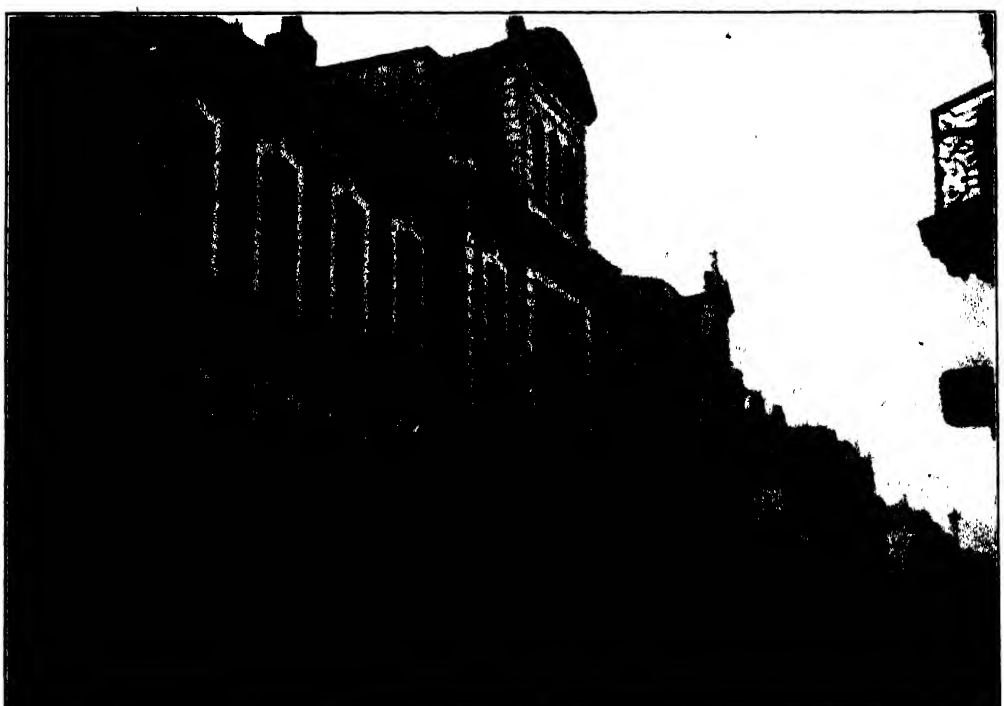
ister their own affairs. This is especially true in the faculties or departments of applied science. That they do not have the full freedom necessary for their growth and development is seen in the splitting off of small groups and the establishment of specialized technical institutes with independent budgets and councils. These institutes, while still nominally under the wings of the faculties of science or medicine, are nevertheless free from direct university control and are free from any interference by the educational authorities at Paris. They are generally self-supporting.

Governmental interference in questions involving traditional rights or precedents is apt to be strenuously resented and stoutly opposed, and whatever may be the interpretation placed upon the clash between students and the ministry over the appointment of the professor of international law in the University of Paris last spring, be it political or otherwise, the result was the vindicating of the authority of the faculties and the establishment of their autonomy upon a firmer foundation than ever before.

The universities of France are for the most part venerable institutions, with records of achievements of which they are justly proud. They have stood through many centuries as pioneers in the search for truth and the dissemination of knowledge and have enjoyed a

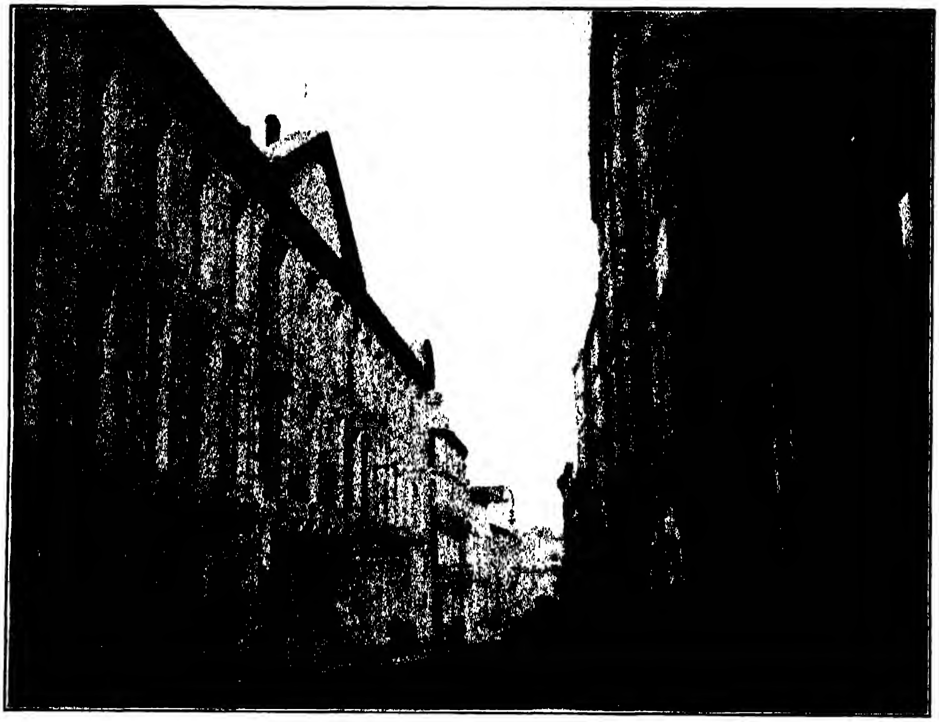


UNIVERSITY OF LILLE, FACULTY OF SCIENCE

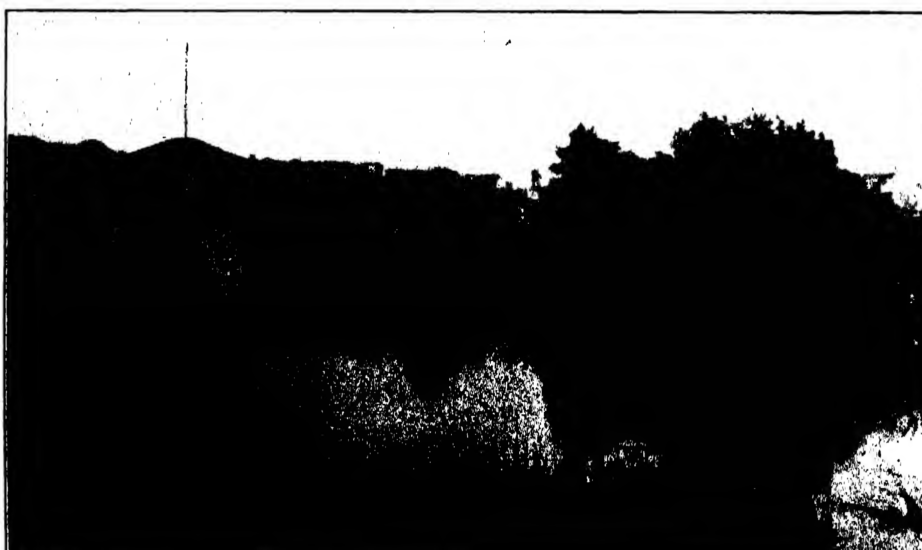


UNIVERSITY OF LILLE, INSTITUT INDUSTRIEL DU NORD

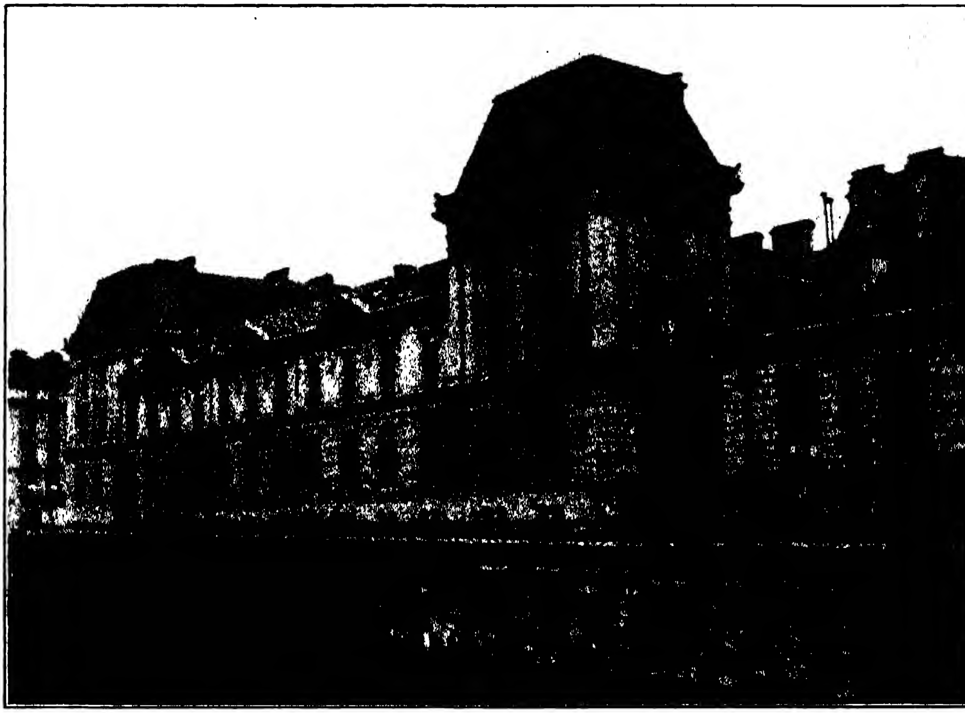
AN INSTITUTION DEVOTED TO GRADUATE WORK IN THE MECHANIC ARTS AND GENERAL ENGINEERING.



RENNES
One of the quaintest of the narrow streets in the very old section of the city.



POITIERS
As seen from the banks of the river Clain.



UNIVERSITY OF RENNES

THE WING OF THE BUILDING SHOWN IN THE PHOTOGRAPH IS DEVOTED TO PHYSICS. THE RIVER IN THE FOREGROUND IS THE MUDDY YELLOW VILAINE, JUSTLY SO NAMED.

degree of academic freedom of which they may well vaunt. Some of them have struggled through most adverse conditions and yet can show an unbroken record of degrees or certificates granted since they were first established.

With the exception of the University of Bologna, the University of Paris is credited with being the oldest in Europe.

There are sixteen universities in France, each taking its name from the city in which it is located. In the order of their founding they are as follows:

Paris—1140 or 1170.
Montpellier—1181 (Reorganized in 1289).
Toulouse—1233.
Grenoble—1339.
Aix-Marseille—1409.
Besançon—Established 1422 at Dôle, transferred to Besançon in 1691.
Poitiers—1431.
Caen—1437.
Bordeaux—1441.
Strasbourg—1567.
Dijon—1722.
Clermont-Ferrand—1808.
Lille—1808.
Lyon—1808.
Rennes—1808.
Nancy—1854.

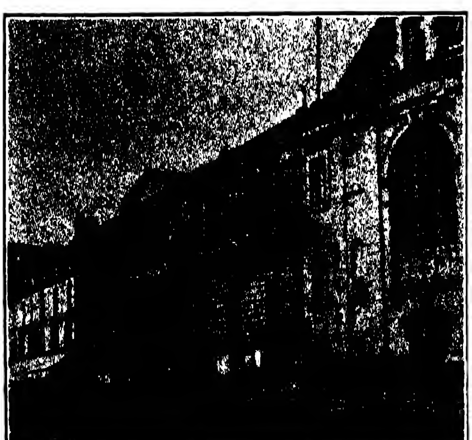
The writer can not vouch for the accuracy of these dates; they are given as the most probable that he has been able to find.

It is probably not strictly correct to use the term "founded" in the sense that we apply it to our American universities; more properly they came into being as recognized centers of learning, forming about one or more "Masters" or "Doctors" whose fame drew to themselves a group of enthusiastic followers or students. These centers eventually developed into the institutions of learn-

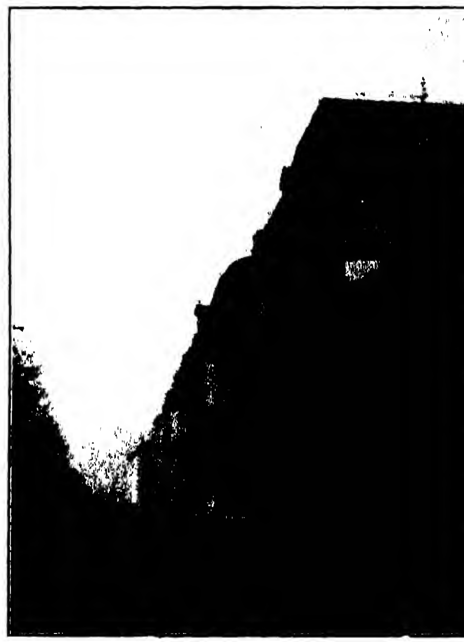
UNIVERSITY OF POITIERS
FACULTY OF SCIENCE.

ing as we know them to-day, thus—like Topsy—they were not born, they just grew.

Until comparatively recently it had been the established idea in France that all the energies of the university in teaching and research should be devoted to pure science, so called. All that which had to do with the applications of science to industry and to daily life—*e.g.*, engineering, industrial chemistry, agriculture, etc.—should be taught in separate institutions, that is, technical schools. The one exception was medicine, which has always been a university study. Thus the necessity for the training of engineers and chemical engineers was met by the creation of separate schools wholly independent of the universities. The development of such departments or colleges under the charters



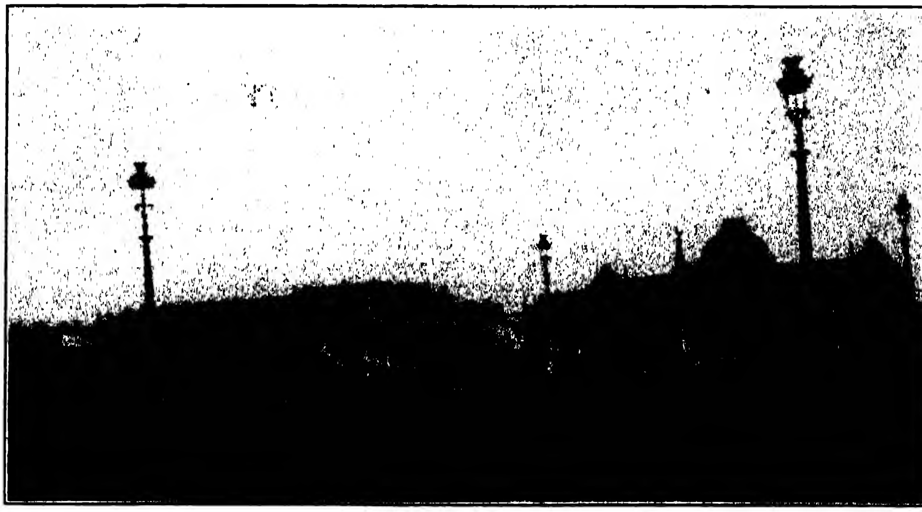
UNIVERSITY OF POITIERS
FACULTY OF LETTERS. THE BUILDING AT THE RIGHT IS THE LIBRARY, WHICH IS RICH IN VERY OLD BOOKS AND MANUSCRIPTS.



UNIVERSITY OF LYON
INSTITUTE OF CHEMISTRY. THE NATIONAL SCHOOL OF TANNERY AND LEATHER MAKING IS HOUSED WITHIN THIS BUILDING.

of the universities as we have them in the United States was considered unorthodox, impractical and inexpedient.

In time, however, some of the far-seeing men of France came to have a broader view, and also began to raise and debate the questions: "What constitutes pure science?" and "When does science cease to be pure and become so commercialized as to be proscribed so far as



LYON

A familiar sight on the streets; milk carts with dogs harnessed underneath; in the background the Faculty of Letters of the University.

UNIVERSITY OF LYON, FACULTY OF SCIENCE

LYON, LE PONT DE L'UNIVERSITE
ONE OF THE MANY HANDSOME BRIDGES ACROSS THE RHONE RIVER.

teaching in a university is concerned?" These men of broad vision through their ability and tireless energy have built up within the faculties of science technical and specialized departments and "schools" which are being carried far beyond anything which we have yet developed in the United States. This movement may be considered to have obtained its incentive in Pasteur and to have been continued through the untiring efforts of the late Albin Haller, of lamented memory.

Since the great war there has been a renaissance of technical education in France and we sometimes read a statement that this interest in the teaching of applied science is the direct result of the war. That this is not wholly true can be readily disproved if we take the trouble to look up the dates of the establishment of technical and specialized courses in the different universities of France. Take, for example, the University of Nancy. Here we find that the following were organized under the administration and supervision of the Faculty of Science:

Institut chimique (Institute of Chemistry) in 1891.

École de Brasserie (School of Brewing) 1893.

Institut d'Electrochimie (Inst. of Electrochemistry) 1897.

Institut Electrotechnique (Institute of Electrical Engineering) 1900.

Institut Agricole (Agricultural Institute) 1901.

Institut Colonial (Colonial Institute) 1902.

Institut de Laiterie (Dairy Institute) 1903.

Institut de Mécanique Appliquée (Institute of Mechanical Engineering) 1906.

Institut de Géologie Appliquée (Institute of Applied Geology) 1910.

École Supérieure de la Métallurgie et de l'Industrie des Mines (School of Metallurgy and Mining) 1919.

Station de recherches hydrauliques (Experiment Station for Hydraulic Research) 1924.

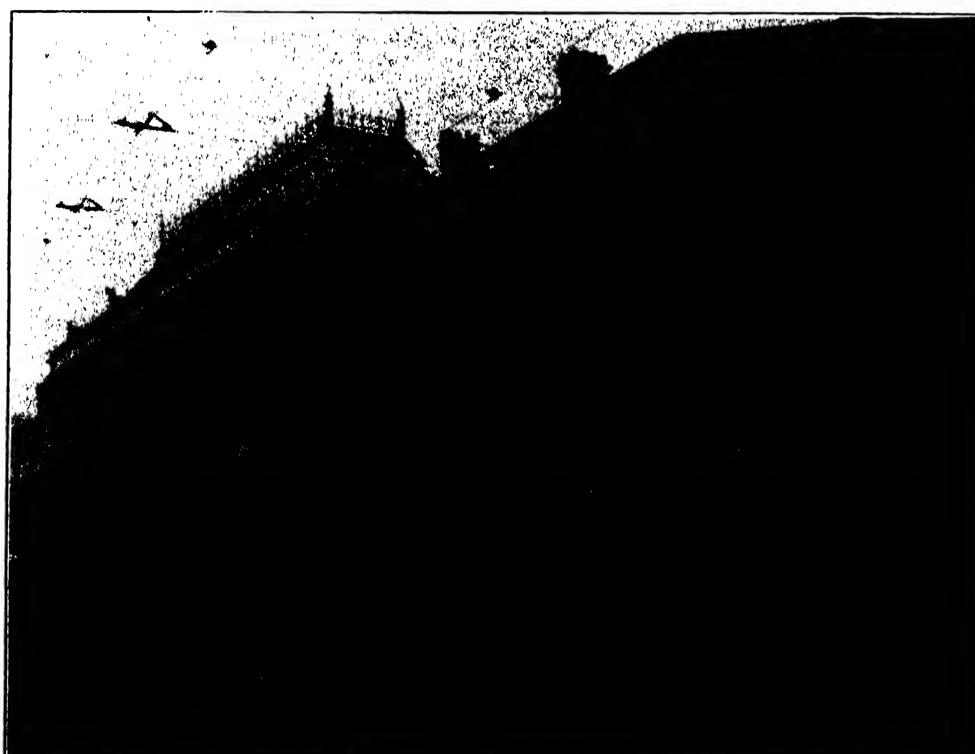
The writer has selected Nancy not only because this university has been a pioneer in the field of modern technical education in France but mainly because he is more familiar with it and its development, since he there passed happy months in study and research many years ago.

It will be noted that this faculty of science has consistently followed, during the last thirty-three years, a policy of great expansion in the teaching of applied science. What is true at Nancy is true at the other universities where the expansion has proceeded equally far and in some instances even farther. It is obvious that the teaching of applied science under the roofs of the universities antedates the war.

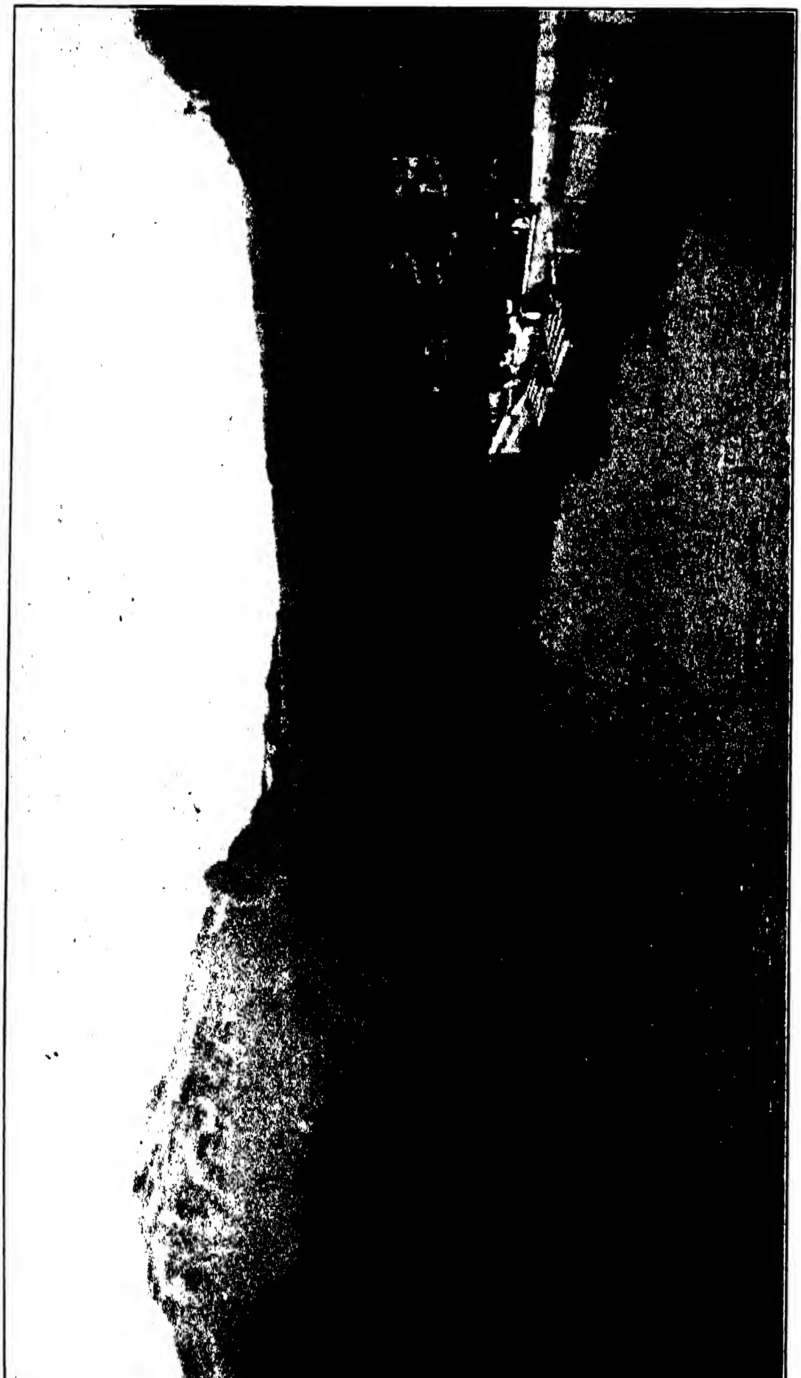
He who to-day visits the universities of France will find everywhere new laboratories being erected or old buildings being remodeled to meet the demand for more space to accommodate the increasing number of students in science and to provide new courses better suited to our modern needs; and he can not fail to be impressed with the admirable manner in which these things are being accomplished. Here we have indisputable evidence that France is rapidly recovering from the effects of the war.

Side by side with this general development of the teaching of applied science, we find an even more interesting educational movement, that which the French call regional instruction or regional specialization.

If the reader will consult the small map of France here reproduced, he will see that the sixteen universities are almost symmetrically distributed throughout the country and are so located geographically as to permit regional in-

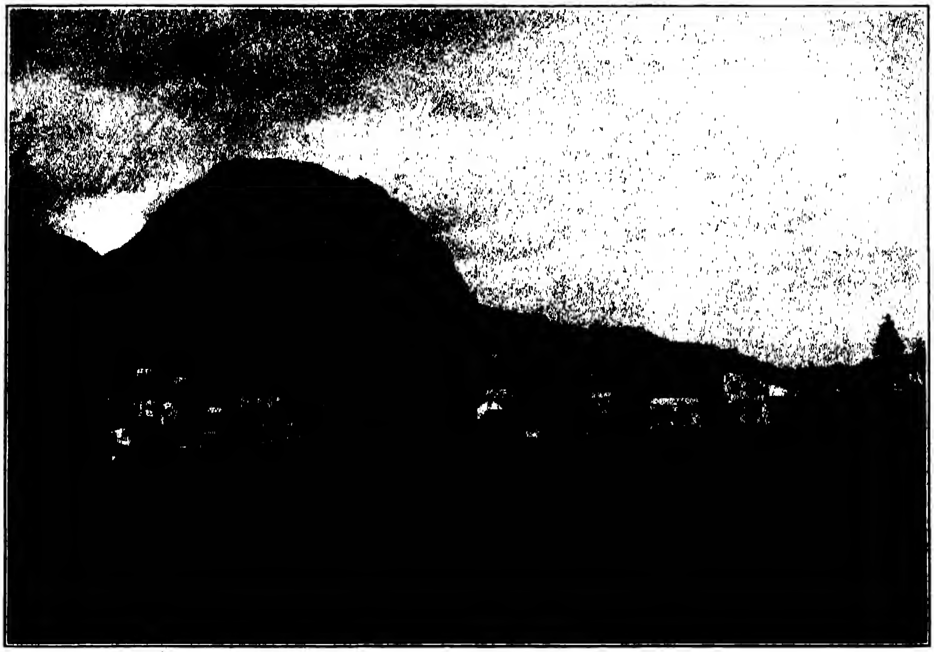


UNIVERSITY OF BORDEAUX, FACULTY OF SCIENCE



GRENOBLE

IS SITUATED ON THE ISERE RIVER IN A VALLEY, HEMMED IN BY MAJESTIC SNOW-CAPPED PEAKS OF THE ALPS.

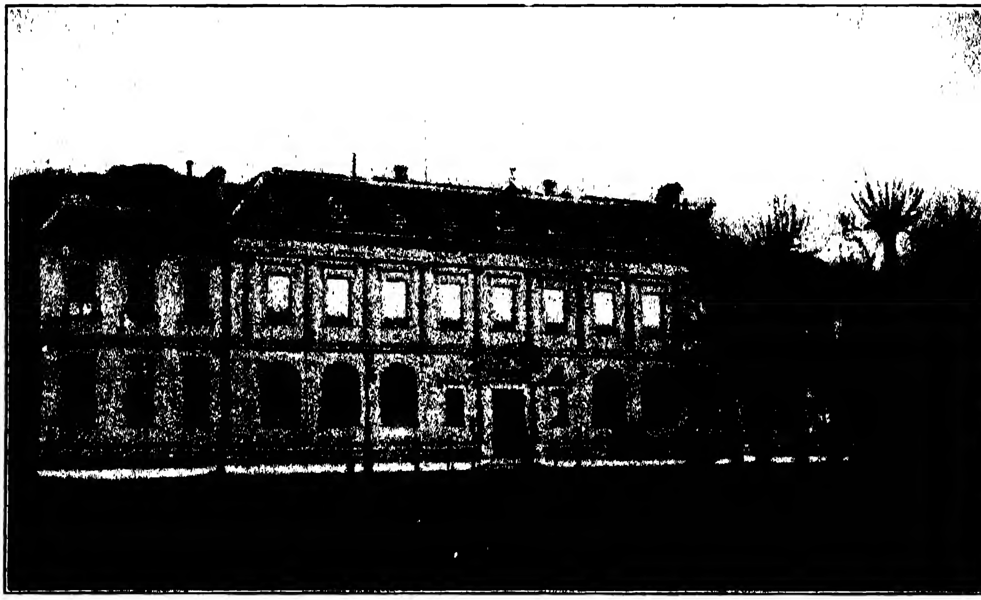


GRENOBLE

Another view from one of the bridges over the Isere river.

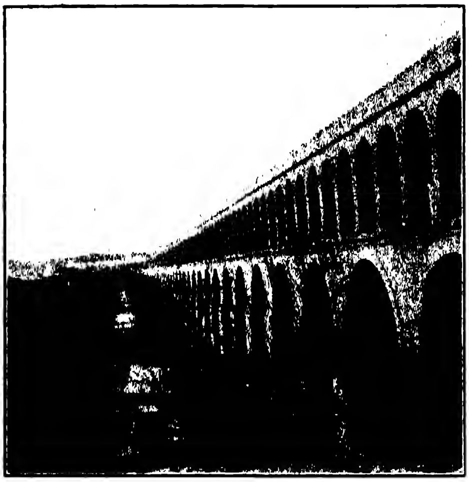
MONTPELLIER

An unique method of improving a dangerous corner for modern traffic.



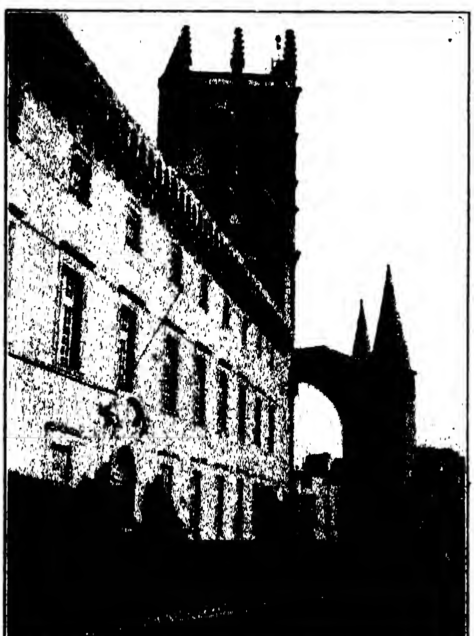
UNIVERSITY OF GRENOBLE, FACULTIES OF LETTERS AND OF SCIENCE

UNIVERSITY OF MONTPELLIER, COURT OF THE INSTITUTE OF CHEMISTRY
A TYPICAL UNIVERSITY COURTYARD. MOST OF THESE COURTYARDS ARE LAID OUT IN CHARMING LITTLE GARDENS.



MONTPELLIER

IN MANY PARTS OF FRANCE THE INFLUENCE OF THE METHODS AND CUSTOMS OF ANCIENT ROME STILL PERSIST; WITNESS THIS FINE AQUEDUCT WHICH BRINGS FROM MANY MILES IN THE HILLS WATER FOR THE MUNICIPALITY.

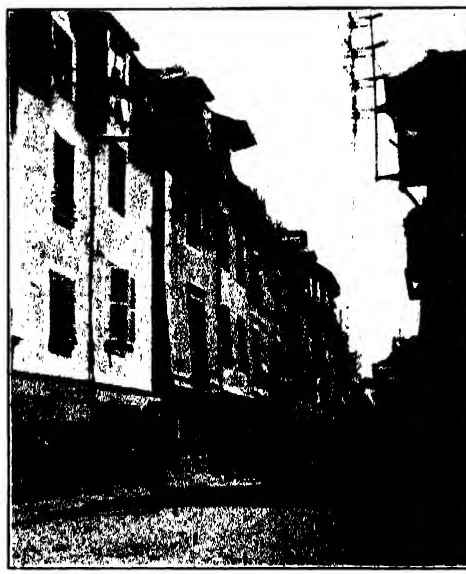


UNIVERSITY OF MONTPELLIER

THE COLLEGE OF MEDICINE IS HOUSED IN THE OLD ARCHBISHOPS' PALACE WHICH ADJOINS THE CATHEDRAL. THE CHURCH PORTAL WITH ITS TWIN ROUND TOWERS IS UNIQUE AND ONE OF THE MOST CURIOUS IN FRANCE.

struction and specialization to be developed to a very high degree of efficiency.

For example, in the neighborhood of Lille are the great plains of Flanders with their ancient flax culture and their coal mines; near Bordeaux and Montpellier are the acres of vineyards; at Marseille we find ourselves in the midst of the olive region and the center of the oil and soap industries, while just to the east of Marseille lie the flower farms and the perfume industries therewith connected. Lyon, Clermont-Ferrand and



UNIVERSITY OF MONTPELLIER

FACULTY OF SCIENCE.

Rennes are important geological centers. So one might go on taking each university center in turn and pointing out how in certain respects, because of its particular situation, each one is able to offer something unique in the way of specialized education, for France is a country of very diversified and localized resources.

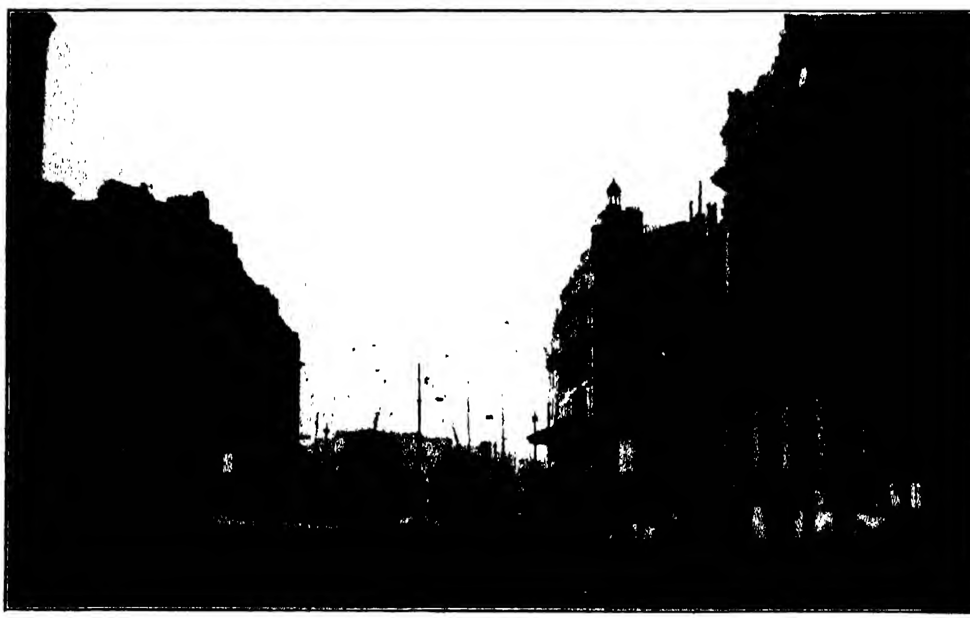
Since regional instruction is becoming of such great importance it is necessary to explain more in detail.

This phase of technical education can be best made clear by giving several ex-

THE LARGE CHEMISTRY AMPHITHEATER, UNIVERSITY OF MARSEILLE

A TYPICAL FRENCH UNIVERSITY LABORATORY

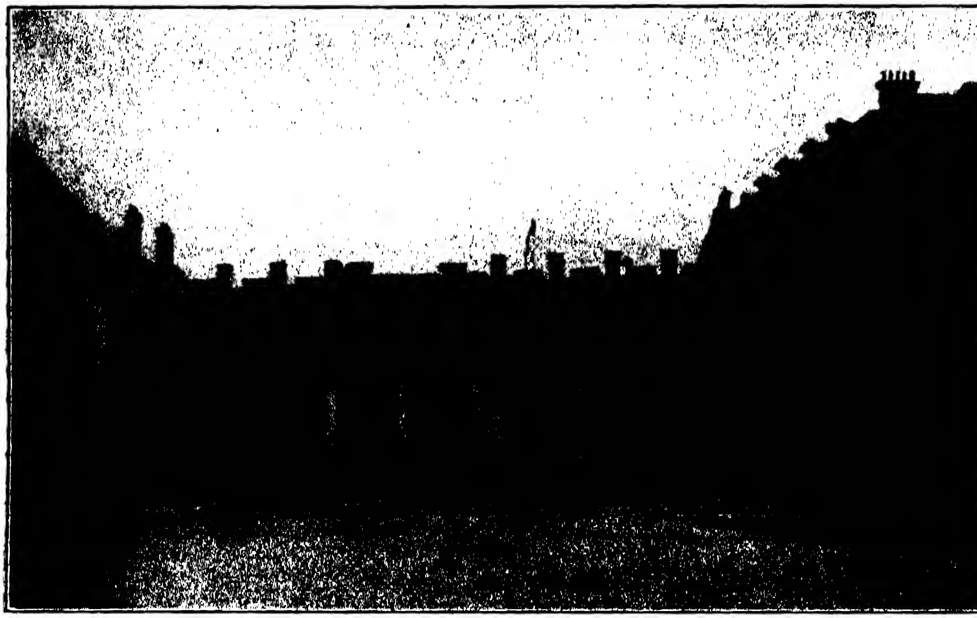
amples. In the southwest of France are found great pine forests and the industries which exploit them, for the manufacture of turpentine, pine oil, rosin and the many substances derived from these materials. Hard by this region is Bordeaux; what is more natural than that we should find in the University of Bordeaux a very flourishing Institut du Pin, which concerns itself with research upon pine tree products of all sorts, especially the development and improvement of manufacturing processes, the utilization of all by-products and the discovery of new compounds. But it must not be thought by the reader that the practical Bordeaux is equally true of all the other regional institutions. As further examples of regional instruction may be mentioned the school of brewing, the school of metallurgy and mining and the Institute of Applied Geology at Nancy, while at Marseille we find exceptional facilities offered for the study of perfumes, fats, oils and soaps; Montpellier, situated at the edge of the great wine region of France, offers instruction in viniculture and vinification under exceptionally favorable conditions because of the great cooperative wine presses near by. These cooperative wine presses and cellars are a new institution in France.



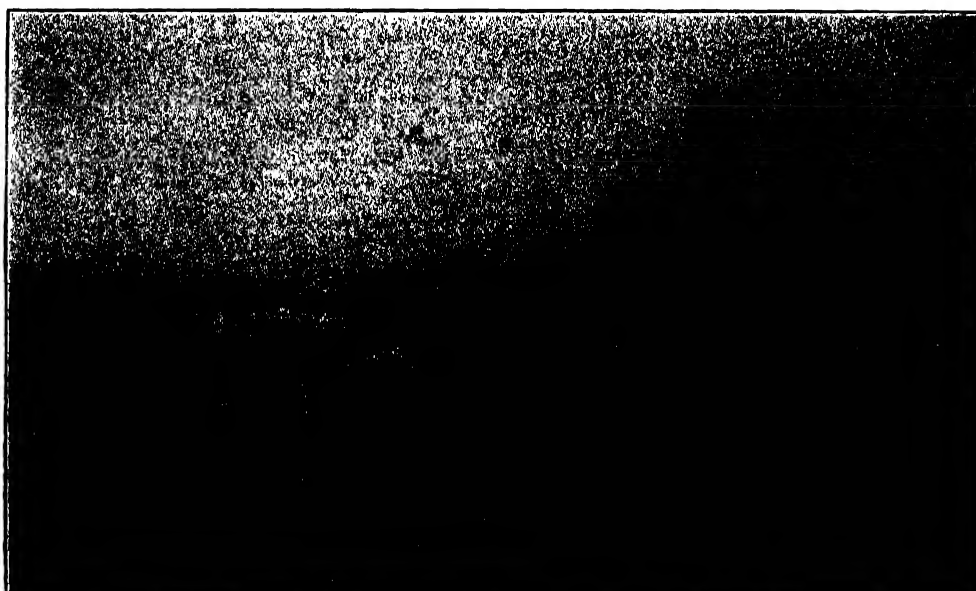
MARSEILLE, RUE CANNEBIERE
ONE OF THE FAMOUS STREETS OF FRANCE.

side is over-emphasized. This is far from being the case, for the Institut du Pin is engaged upon the investigation of a very intricate class of compounds, the terpenes. When last year it was the writer's privilege to visit the Institut du Pin, he found many investigators engaged in research upon problems of pure chemistry without any idea of commercial applications. That which is true at They appear to be efficiently managed and so far as the writer was able to ascertain the members of the associations are satisfied and well pleased with the results which have been accomplished. One of these institutions has a storage capacity of 160,000 hectoliters of wine.

Then we have the Institut Industriel du Nord, at Lille, mainly for mining engineers, the Institut du Petrole, at Stras-



UNIVERSITY OF MARSEILLE, FACULTY OF SCIENCE
ONE SIDE OF THE UNIVERSITY QUADRANGLE.



MARSEILLE HARBOR
WITH THE CATHEDRAL AT THE RIGHT; A STRIKING EDIFICE IN POLYCHROME SAND-STONE IN SEMI-BYZANTINE STYLE.

bourg, and elaborate provision made for studies in hydroelectric engineering and electrochemistry at Toulouse, Lyon, Nancy and Grenoble. These regional institutes are interesting not only because they deal with industrial problems and industrial developments of a more or less local nature but because they are examples of an educational movement of the highest importance, of which we have no counterpart in the United States, a sort of industrial supergraduate work. These "schools" and others of a non-local character cater to engineers who are already placed in the industries, who wish in a short period to broaden their training or to carry on research for which their "plants" are ill fitted. In addition to the institutions already mentioned we find a school of paper-making at Grenoble, of tannery and leather making at Lyon, the Institut des Carburants at Montpellier, the Institut Technique Supérieur and the Institut Colonial of Marseille (to which may be added special courses in commercial economics); the Geophysical Institute at Strasbourg and many others.

The examples given, it will be noted, are all comprehended in the term engineering or physical sciences. Space will not permit consideration of similar institutions provided for those interested in medicine, in agriculture and in the biological sciences. Nevertheless, I can not refrain from at least mentioning the marvelous Pasteur and hygienic institutes to be found all over France, splendidly equipped and administered by exceptionally able, experienced and enthusiastic staffs who follow in the footsteps of their great master, Pasteur.

In every one of the large universities there are to be found courses in special fields in all the great fundamental sciences, courses given by scientists of world-wide celebrity who devote practically their entire time to instruction and research in the specialized field in which they have attained distinction. Their laboratories are admirably equipped, the material for study and research remarkably extensive and complete; in these points they are on the whole superior to our own, but unfortunately at present they lack funds for maintenance and expansion, for proper heating and service, for repairs and alterations. Yet they "carry on" in a way which puts most of our American institutions to shame.

For the botanist there are botanical stations in the Vosges and in the Alps and Pyrenees, for the biologist, biological stations on both fresh and salt water; nor should I forget to mention the courses in applied botany given by that horticultural wizard of the University of Rennes, Professor Lucien Daniel, who may well be called the Burbank of France, whose remarkable experiments on budding and grafting bid fair to open a whole new field in the propagation of plants.

France is the land of song and story, the home of art and things beautiful, a nation of cheerful, happy, friendly, frugal people, a country of picturesque, wonderfully diversified scenery and remarkably well-preserved ancient structures. For the student there is much to see and enjoy outside the cloistered halls of the universities.

Where can the traveler find more pleasing mountain views and vistas than in the Vosges, the Pyrenees, the Jura or the Alps? In what other country can one find a Carcassonne, a Mont St. Michel, a Maison Carré, an Aigue-Morte or even a quaint dead village like little Brouage? And where will he find anything more beautiful or more glorious or more inspiring than the sunlight streaming through those wondrous ancient windows of Chartres?

SCIENTIFIC WORK OF THE MAUD EXPEDITION, 1922-1925[1]

By H. U. SVERDRUP
IN CHARGE OF THE SCIENTIFIC WORK OF THE EXPEDITION

CAPTAIN ROALD AMUNDSEN'S ship *Maud* left Norway in July, 1918, with the intention of following the Siberian coast to the vicinity of the New Siberian Islands, penetrating into the drift-ice, and, if possible, being carried across the Arctic Sea to the vicinity of Spitzbergen. However, on account of unfavorable ice-conditions, it was necessary for the expedition to winter three times on the Siberian coast and, in 1921, to go to Seattle for repairs and replenishment of provisions.

The *Maud* left Seattle again on June 3, 1922, in order to resume her task in the Arctic. The main object was, as previously, to make scientific observations of interest in various branches of geophysics.

We could not expect to contribute to the geographical knowledge of the Arctic region, because it was improbable that the drift should carry us across the great unknown area within the Arctic Sea. To Captain Amundsen, however, the exploration of this unknown area had always been a fascinating task. Therefore, after having organized and equipped the Drift Expedition in the best way possible, he resolved to leave the ship and try to fly across the Arctic Sea. Accordingly, he left us at Point Hope, Alaska, and went with a trading schooner to Point Barrow.

I shall not here enter upon his first unsuccessful attempts, nor dwell upon his and Mr. Ellsworth's marvelous achievement during the past summer. Captain Amundsen and Mr. Ellsworth have not yet reached their goal; however, they are, as you know, planning a flight with a dirigible airship from Spitzbergen to Alaska during the summer of 1926.

Captain Amundsen left us on July 28, 1922, and the *Maud* headed towards the west under the command of Captain Oscar Wisting. We met the ice a short distance from Point Hope but succeeded in penetrating to Herald Island, where we were closed in by the ice on August 8, 1922. For one year we drifted towards the west-northwest in a zigzag course, depending mainly upon the wind and were, at the beginning of September, 1923, in latitude 76° 17′ north, being east of De Long Islands. We hoped to drift on the northern side of these islands and perhaps cross to Spitzbergen along a route more northerly than the one taken by the *Fram* during the famous drift of Dr. Nansen, 1893 to 1896. However, continuous northerly winds carried us 100 miles to the south. The winter of 1923–1924 was spent in latitude 75° north, to the southward of De Long Islands. At the end of February, 1924, Captain Wisting received a wireless message from Captain Amundsen asking him to get out of the ice, if possible, and return to Nome in the summer of 1924. In the spring and summer we were again carried towards west-northwest. The ice opened, and on August 9 we could move under the ship's own power after having drifted helplessly for two years. However, we

[1] Address delivered December 1, 1925, at the Carnegie Institution of Washington, Washington, D. C.

did not reach Nome in the summer of 1924, but were stopped by the ice at the Bear Islands, where we had to stay for ten months. We finally reached Nome on August 22, 1925.

When leaving Point Hope, our party consisted of eight men, including a native boy from the Siberian coast who acted as cabin-boy. We lost one of our comrades from inflammation of the brain in July, 1923, after one year in the ice, and buried his body in sailor fashion by lowering it in a space between the ice-floes. During the remaining two years we saw no human beings outside of our own small party before March, 1925, when we were visited by half-breed Russians from the settlement at the Kolyma River.

During the drift and later we did not pass through any geographically unknown region. We carried an airplane, a Curtiss Oriole, with which we hoped to extend the geographical exploration to both sides of our route. The starting and landing conditions on the ice were, however, very unfavorable. Two successful trial-flights were made in spite of the difficulties, but during the third flight the motor missed fire at the take-off, the pilot had to land on rough ice, and the plane was damaged beyond repair.

Our zigzag route was determined by frequent astronomic observations, generally two or three a week. In winter it was often a chilly amusement to take these observations and the observer had to dress up for the occasion, but in summer it was delightful because the temperature then was around the freezing-point. The astronomic observations were generally taken on the ice, but the instruments were never left there. They were always carried on board after the observations, because the ice might at any time break up and the instruments might be damaged or lost.

The astronomic observations, of course, had to be taken from the very beginning of the drift in order to follow our route step by step. Simultaneously with these, the observations of the magnetic elements were made. These observations had to be taken on the ice at such a distance from the ship that the disturbing influence of the magnetic iron-masses on board was eliminated. The *Maud* was far from being non-magnetic. The first observations were taken without any other shelter than the protection against the wind which a large ice-hummock might give. Later, when our surroundings became more solid, we built an ice-house which we used to call the "crystal palace." The ice-house was equipped with electric lights and a non-magnetic stove which, in winter, brought the temperature up to about —10° Fahrenheit. The magnetic and other observations were taken in this house during the first winter, 1922–1923.

The magnetic instruments were loaned to the expedition by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, which had paid special attention to make them suitable for use in the Arctic. The greatest improvement was that all metal parts which had to be touched by the fingers were covered with celluloid caps. If metal is touched at low temperatures by a cold finger, the result is frequently a white, frozen spot on the finger, but the celluloid caps could be handled without great inconvenience. The magnetic needles, however, could not be provided with celluloid protection, and they had to be handled with uncovered hands. They often left a white line which, later, when the observer returned to a heated room, turned black and caused "toothache" in the finger. All of us had blackened fingertips in the winter.

Our "crystal palace" did not survive the Arctic summer; it melted in June, and in summer we had to take the observations in a tent. This observing tent was used during the entire winter of 1923–1924 because a new "crystal pal-

ace," which had been built in October, 1923, disappeared when the ice broke to pieces around the ship at the end of the month, and because our surroundings later were constantly changing. Our tent undertook several independent expeditions as the ice broke between the ship and the tent and the parts on both sides of the crack were displaced in relation to each other. On one occasion we thought the tent was lost. The ice broke on Thursday afternoon, and the tent rapidly disappeared out of sight between hummocks and pressure-ridges. Searching parties were out looking for it on Friday and Saturday, but without success. On Sunday Mr. Hansen, the mate, and I took a walk, following a lane which recently had been covered with young ice on which walking was easy. We thought we were going in the opposite direction to the one in which the tent was supposed to be, but about two miles from the ship we saw human tracks on an old ice-floe and an inspection soon revealed that we had encountered an old acquaintance, which previously had been located close to the ship. Looking around, we saw the tent standing there unharmed; we took it down and carried it back to the ship in triumph.

Continuous records of the magnetic elements could not be obtained on the drift-ice because the ice-fields were always moving, turning and twisting, making a permanent orientation impossible. The conditions were different during the winter of 1924–1925, when we were frozen in close to the coast on motionless ice. There we used a large tent for ordinary magnetic observations and installed an instrument for photographic registration of the declination in a light-tight case within the smaller tent previously used.

I shall not enter upon the results of our magnetic observations during the drift, but wish to mention the character of the diurnal variation of the magnetic declination as recorded during the winter of 1924–1925. The most remarkable feature is the small range of the diurnal variation in the middle of the winter and the rapid increase of this range in the spring. It is to be hoped that our records, combined with previous results, may furnish sufficient data for the application of corrections for diurnal variation to the declinations observed on or near the Siberian coast.

The records may also be of value in the study of magnetic storms. There is a close relation between the occurrence of magnetic storms and the occurrence of the aurora borealis. We always had to keep night-watches. We used to stay up for two hours each, and the watchman was instructed to make frequent notes regarding the form, amount and intensity of the aurora. We succeeded in taking several pictures of brilliant displays, using cameras developed by Professor Störmer, of Oslo.

The atmospheric-electric observations in the winter of 1922–1923, which were confined to observations of the potential gradient, were also taken in the ice-house.

In 1922 the Department of Terrestrial Magnetism had drawn our especial attention to the value of observations of the diurnal variation of the gradient over the Arctic Sea. One of the most interesting results of the atmospheric-electric work carried out on board the *Carnegie* during 1915 to 1921 was that this variation follows universal time over the oceans, the maximum value being reached simultaneously over all the oceans. Our special task was to ascertain whether this law for the variation was valid over the Polar Sea as well.

During the first winter the diurnal variation of the potential gradient was followed by eye-observations through twenty-four hours, but we found that we naturally would save time and materially increase the amount of data if we

could record the gradient continuously. I, therefore, asked our aviator, Mr. Dahl, who is a genius as an instrument-designer and maker, to construct a recording electrometer. The instrument itself did not present any difficulties, but these arose when a perfect electrostatic insulation was to be insured. Amber is generally used for insulation, but we had no supply of amber. The difficulty was finally overcome by my sacrificing a perfectly good amber pipe-stem.

Our recording electrometer was placed in an unheated room on deck and became, therefore, covered with frost on the outside, but this circumstance did not influence the efficiency of the instrument. The records gave, however, only relative values of the gradient. In order to reduce them to absolute values, simultaneous eye-observations were carried out from time to time on smooth ice at a sufficient distance from the ship. As a matter of precaution in case a polar bear should be too curious, the observer was always armed when he had to go some distance from the ship. I may mention that the observers were never disturbed.

We were unable to secure any observations during the summer because a satisfactory insulation could not be maintained on account of the dampness of the air. Our records are, therefore, limited to the cold months, October to April. When referred to universal time, the records for this season are in excellent agreement with the results obtained on the *Carnegie*. These are represented by the lower curve in Figure 1, while the three upper curves represent our preliminary results during the three winters. Our observations from the Polar Sea thus confirm the important conclusion regarding the universal character of the diurnal variation of the potential gradient drawn from the observations carried out on the *Carnegie* during cruises over all oceans.

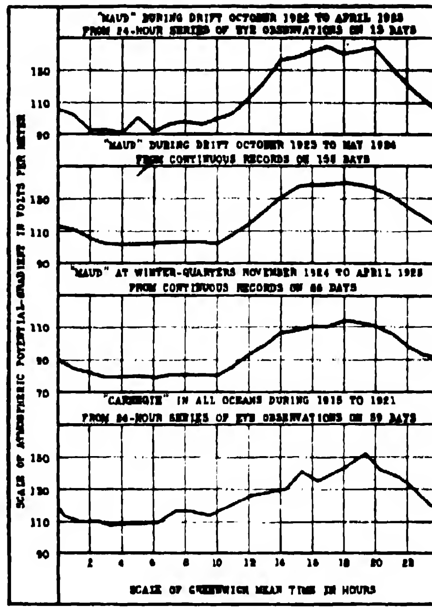


FIG. 1. DIURNAL VARIATION OF THE POTENTIAL GRADIENT OF THE ATMOSPHERE.

The greatest value of the gradient occurs at 18^h Greenwich mean time, which is approximately the time when the sun is in the meridian of the magnetic poles of the earth. This fact indicates a close relationship between the magnetic and electric fields of the earth, but the character of this relationship has yet to be explained.

Meteorological observations were taken regularly six times daily during the three years, and for the entire period continuous records of the barometric pressure, the temperature and humidity of the air, the direction and velocity of the wind and the duration of sunshine are available. Our meteorological screen was placed on the roof covering the deck, while a snow-gauge for measuring the amount of precipitation was placed on the ice. Special studies of the humidity of the air at low temperatures and of the formation of frost were carried out by the assistant scientist, Mr. Malmgren, who devised and, assisted by Mr. Dahl,

constructed a special instrument for recording the frost-formation. Special studies of the daily variation of the temperature of the air were also carried out, but I can not enter upon a discussion of the results of these investigations nor of the results of the general meteorological observations. Instead, I shall turn to our upper-air observations.

The direction and velocity of the wind aloft was determined by means of pilot balloons, 552 of which were released. These wind observations indirectly give interesting information regarding the average temperature-distribution at great altitudes. In Figure 2 average wind-velocities in the free atmosphere are represented by three curves, (1) representing the velocities over the North-Atlantic trade-wind region, (2) over middle Europe, and (3) over the part of the

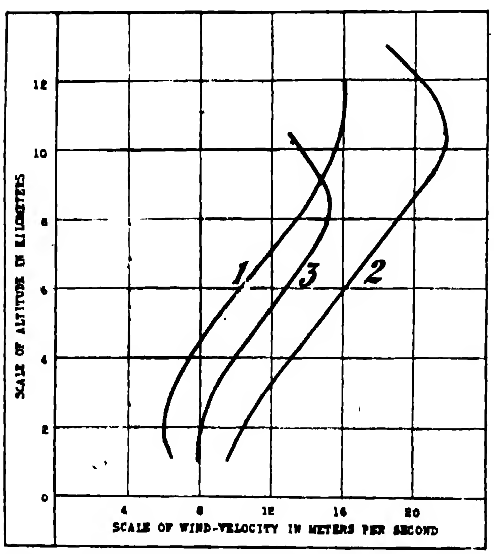


FIG. 2. AVERAGE WIND-VELOCITY AS A FUNCTION OF ALTITUDE.

Arctic which we have traversed. I wish to draw your attention to the wind-maximum which the last two curves show at great altitudes. This maximum is known to occur at an important boundary surface of the atmosphere, which has been called the "ceiling of the troposphere." Below the maximum, within the region called the troposphere, the temperature decreases with altitude, but above the maximum, within the stratosphere, it remains constant. These curves show that the ceiling of the troposphere above the North-Atlantic trade-wind lies higher than 12 kilometers; in fact, it is found at an altitude of 16 kilometers. In the southern part of this country the corresponding altitude is 12.5 kilometers, in the northern 11 kilometers, in middle Europe 10.5 kilometers, and over the part of the Arctic we have traversed it is only 8.5 kilometers. Our results confirm the conclusion that the distance to the ceiling of the troposphere decreases towards the Pole.

Direct observations of the temperature of the free air are available from the lowest part of the atmosphere and have been obtained by means of self-recording instruments lifted by kites. The instruments were tested in the laboratory of the *Maud* from time to time. The big kite-reel for letting out and hauling in the kites was placed on deck. The wire could be guided in any desired direction, depending upon the direction of the wind, by means of a special pulley mounted on the ice a short distance from the ship. The first pulley was fastened permanently to the ice but was lost during an ice-pressure. We, therefore, mounted the second pulley on a sledge, which could be taken on board at short notice. The kites, which were mostly used, were loaned to the expedition by the United States Weather Bureau. They were built sturdily, but were subject to hard usage on account of the difficult conditions. They, therefore, had to be repaired frequently, both in winter and in summer. So little was left of the original kites after three years that they had to be entered as lost.

The most interesting result from the kite-ascents is, perhaps, that in winter the temperature of the air practically always is lower close to the ice than

three hundred meters above the ice. The mean temperatures derived from sixty ascents made during the drift in the coldest months, November to March, are represented in Figure 3. The full curve represents the conditions during the kite-ascents, that is, when the average wind-velocity at the ice was about eleven miles per hour. The temperature decreases with altitude in the first 136 meters, but increases higher up, first very rapidly and then more slowly. The mean temperature at the ice is – 28.4° Centigrade, while at an altitude of 1,000 meters it is only – 20.3° Centigrade. The dashed

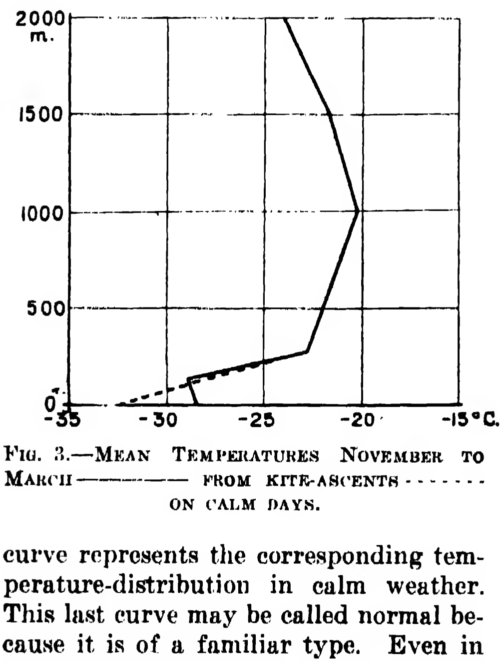


FIG. 3.—MEAN TEMPERATURES NOVEMBER TO MARCH ———— FROM KITE-ASCENTS - - - - - - ON CALM DAYS.

curve represents the corresponding temperature-distribution in calm weather. This last curve may be called normal because it is of a familiar type. Even in this latitude the lowest temperatures are found close to the ground on clear and calm days in winter because the air is cooled from below by contact with the surface, which loses heat by radiation. When a wind arises, however, the air generally becomes mixed to a considerable altitude on account of the numerous eddies which are formed along the ground, and a normal decrease of temperature with altitude is more or less established. The characteristic feature encountered over the Polar Sea is evidently that this forced mixing is limited to a thin layer of air directly above the ice. Over this layer comes a marked inversion, forming a surface of discontinuity which prevents further mixing.

The wind observations by pilot balloons confirm this result. At the ice the observed wind-velocities were always small, undoubtedly on account of the great resistance offered by the rough ice, but above the inversion, where the warmer air was sliding over the cold layer, strong winds were met.

The temperature-distribution here described was always present in winter, independent of the direction from which the wind was blowing. Considering this and the uniform meteorological conditions over the Polar Sea, it seems justified to conclude that in winter the whole Polar Sea is covered by a thin layer of cold air which, to a great extent, is isolated from the atmosphere above it. Such conditions are possible on a frozen sea, which, disregarding the roughness of the ice, has the character of a vast plane. A sharp surface of discontinuity can exist over a vast plane even when the wind is blowing, but it can not exist over a mountainous continent because it would soon be broken up on account of the differences in elevation.

Since the cover of cold air is isolated from the free atmosphere above it, the temperature of this cover must depend, to a great extent, upon the temperature of the ice-surface with which it is in contact. Particularly, the lowest temperatures of the air must correspond closely to the lowest temperatures of the surface. During the six winters I have spent on or off the Siberian coast the minimum temperature always has been close to 50° below zero, Fahrenheit. There must be some reason why this limit is reached but not passed. The answer seems very simple. The surface of the ice, which is covered by a very thin layer of hard snow, loses heat by radia-

tion to space at night. The temperature would sink to very low values during the long, continuous winter-night if this loss were not compensated in some way. It is compensated. Heat is constantly conducted through the ice to the surface from the underlying sea-water, which has a constant temperature of 29° above zero, Fahrenheit, the freezing-point of the sea-water. The amount of heat conducted to the surface increases when the temperature of the surface sinks, but the amount of heat lost by radiation decreases at the same time. Loss and gain, therefore, must equalize each other at a certain temperature, and when this limit is reached the temperature of the surface can not sink any further.

We have made extensive measurements of the heat lost by radiation and the heat conducted through the ice, and have found that loss and gain, on the average, compensate each other at about -40° Fahrenheit and at about -50° Fahrenheit under exceptional circumstances. The conditions seem, therefore, to be actually as simple as assumed. The minimum temperature of the air is reached when the surface receives as much heat from the sea as it loses by radiation to space.

The instrument for measuring radiation was loaned to the expedition by the Smithsonian Institution, and was used extensively for determining not only the loss of heat at night but also the amount of heat received from the sky and the sun in the daytime. For this purpose it was mounted beside the instrument for recording the duration of sunshine and was made self-recording, thanks to the ingenuity of Mr. Dahl. The recorder was a very sensitive galvanometer. The pen of the galvanometer was pressed down by an arm operated by an electromagnet at intervals of four minutes.

Our computation of the amount of heat conducted through the sea-ice was based on measurements of the temperature within the ice at various depths. For this purpose we used resistance thermometers, which were buried in the ice. The leads were taken into the ice-house, where the readings were made during the first winter. In summer the readings were taken on the ice without any shelter. In the spring of 1924 the ice-floe in which the thermometers were buried was carried away from the ship, and we had to start out in a boat in search of it in order to obtain the daily reading. The thermometers were finally lost when the ice-floe upon which they were mounted was crushed, but not before a sufficient number of observations had been obtained.

Our knowledge of the physical properties of the sea-ice was materially increased by experimental studies which Mr. Malmgren undertook under very trying conditions. His results show that the newly frozen sea-ice, which contains a great quantity of salt, really consists of pure ice with enclosures of brine. With any change in temperature, part of the brine is tranformed primarily into pure ice, or *vice versa*. The expansion or contraction of the ice and its specific heat depend, to a great extent, upon the intensity of this process. The problem can be treated mathematically, and there is an excellent agreement between the computed and experimental results.

In summer, when the temperature of the ice approaches the melting-point, the enclosures of brine increase so much that the ice becomes porous, the brine trickles down through, and the upper part of the ice, which previously was too salty for drinking purposes, becomes absolutely fresh.

Our daily soundings showed that during the whole time of our drift we had remained on the continental shelf; the depth varied for long periods between twenty and thirty fathoms, although the distance to the coast was three hundred miles. A hole in the ice was kept open for the soundings. Once a week we determined the temperature at various

depths by reversing thermometers and collected water-samples for investigation of the density, salinity and amount of oxygen of the sea-water. Speed was essential when the water-samples were taken in winter. After the water-bottle was hauled up, it had to be detached from the wire as quickly as possible and the observer had to run headlong on board with it to prevent the contents from freezing.

The water-bottles were emptied in the laboratory, where samples for the various investigations were taken to be examined. The specific gravity, for instance, was determined with a high degree of accuracy by using Nansen's hydrometer of total immersion, and the amount of chlorine from which the specific gravity could be computed independently was determined by careful titration. Systematic differences amounting to five in the 5th decimal between the computed and observed densities indicate that the composition of the sea-water is altered by freezing. Chemical analyses of the samples we are bringing home may throw light on the character of these changes.

We found, furthermore, that over a large part of the shelf the density of the sea-water remained constant to a depth of twenty fathoms, where a sudden increase took place. The lighter surface-water was separated from the heavier bottom-water by a marked surface of discontinuity, which is of the same importance to the currents in the sea as is the surface of discontinuity in the air above the ice to the air-currents or winds.

We had no biologist on board, and I am, therefore, unable to give any account of the life in the sea. We did, however, collect samples of plankton and specimens from the bottom of the sea, which we have preserved and are bringing home for further study.

The investigation of the tidal phenomena has taken much of our time and brought interesting results. The tides were recorded continuously at Bear Islands by a tidal gauge constructed on board. On the shelf the range of tide and time of high water were determined at several stations by means of direct soundings, and the tidal currents were measured or recorded continuously. At first we used the current-meter constructed by Ekman, but soon found that this delicate instrument was too difficult to handle in low temperature. The moment it was hauled up for reading it became coated with ice and had to be taken indoors and heated before it could be lowered again. We needed an instrument which could be left lowered for weeks, recording the currents under the ice electrically in the laboratory. Mr. Dahl and I succeeded in designing an instrument of this kind, which recorded direction and velocity of the currents by means of a single electric circuit, but I can not enter upon the details of construction. Two types were developed, one of which was suspended on a single wire and recorded the direction by means of a compass-needle, and another which was suspended in a bifilar frame and recorded the direction relative to the orientation of this frame. The latter type was kept in operation during the major part of fourteen months. By lowering it to various depths we could obtain a full knowledge of the tidal currents from the ice to the bottom. The tidal motion of the ice itself was determined directly by a simpler method.

Our main results, representing the conditions at spring-tide, have been entered on the map reproduced in Figure 4. The character of the tidal currents is indicated by the ellipses. They signify that the currents are rotating, the arrow-heads on the ellipses indicating the direction of rotation, which is clockwise within the entire region. The ratio between the axes of the ellipses corresponds to the ratio between the maximum and minimum current. The

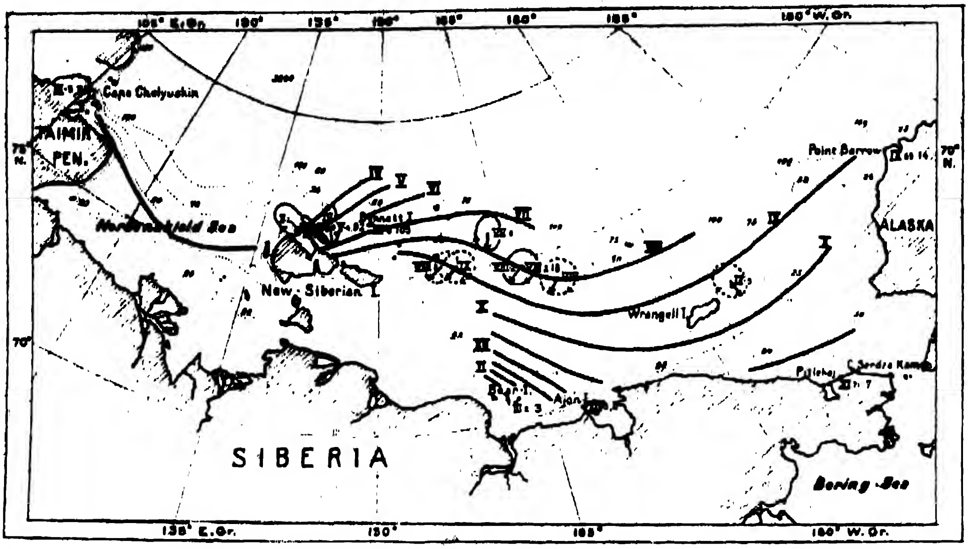


FIG. 4.—RESULTS OF TIDAL OBSERVATIONS, 1918–1924.

direction of maximum current is indicated by an arrow, and the Greenwich lunar time of maximum current is entered. Furthermore, the Greenwich lunar time of high water and the range of the spring-tide are entered at all stations where data were available. Previous observations have been utilized from Point Barrow, Pitlekai and Bennett Island, but all others represent results obtained during the six years the *Maud* has spent in the Arctic.

By means of the data entered on this map it is possible to draw lines showing the crest of the tidal wave for certain hours of Greenwich lunar time. The heavy lines show these crests, and the corresponding hours have been entered. The wave appears to reach the shelf from the north and seems to come directly across the Polar Sea from the Atlantic side without meeting any obstruction formed by masses of land. The late Professor R. A. Harris, of the United States Coast and Geodetic Survey, compiled and discussed in 1911 all available tidal observations from the Arctic region. He arrived at the conclusion that the tidal wave within the region here dealt with travels practically parallel to the coast, and assumed, therefore, that a great area of land or very shallow water existed within the unknown area north of Alaska and Siberia. His conception of the direction in which the wave proceeds seems, however, to be erroneous, as the tidal phenomena seem to indicate no existence of extensive land masses between Alaska and the Pole.

The lines in this map unite all observations in a satisfactory way in a consistent picture of a progressive wave, but the picture has little in common, indeed, with the picture of a long wave, which proceeds under the influence of gravitational forces only. Within such a wave the tidal current should be alternating, not rotating, the range of the tide should be approximately constant along the wave-crest, and the rate of progress should depend only upon the depth of the sea. We find, however, that the currents are rotating clockwise within the whole region and are almost circular at great distances from the coast, but they are approximately alternating where the wave proceeds along the northern side of the New Siberian Islands. The range of the tide varies extremely along the wave-crest, decreasing from right to left

when referred to an observer looking in the direction in which the wave proceeds, namely, from 210 centimeters close to the New Siberian Islands, 105 centimeters at Bennett Island, 18 centimeters at the middle of the shelf, and only 14 centimeters at Point Barrow. The rate of progress does not show a simple relation to the depth, but is too great where the currents are almost circular and is too small where the currents are almost alternating. These features, as a partly new theoretical investigation shows, can be explained as the result of the rotation of the earth. The forces of inertia arising from the rotation have to be taken into account as well as the gravitational forces.

There are still other complications. The tidal currents vary extremely with depth, according to our observations, and this must be due to the resistance which the currents meet, partly under the rough ice and partly along the bottom. The energy of the wave is dissipated on account of this resistance, and evidence of this is found in the fact that the range of the tide decreases when the wave approaches the coast. At the border of the shelf the range is eighteen centimeters, at Ayon Island five centimeters and at Bear Islands only a little more than three centimeters.

To some degree it is possible to investigate theoretically the influence of the resistance upon the character of the tidal currents and the range of the tide. The upper part of Figure 5 shows the hydrodynamic equations, and the lower part shows a solution containing four complex constants which must be determined by the boundary conditions. The formulae are not beautiful, but have proven invaluable as may be seen from the next figure.

In the upper part of Figure 6 actually observed tidal currents are represented. To the left is a vertical section in which the component of the current in the supposed direction of progress of the wave is represented for each hour. To the right are two horizontal sections in which the currents in two depths are represented by central vector diagrams. The heavy curve in the left-hand diagram represents the density. From the shape of this curve one is justified to assume that the lack of tidal motion down to forty meters is due to great resistance, that the strong tidal currents are developed where the heavy bottom-water slides under the lighter surface-

$$\frac{\partial u}{\partial t} = -g\frac{\partial \zeta}{\partial x} + 2\omega v + \eta\frac{\partial^2 u}{\partial z^2}$$

$$\frac{\partial v}{\partial t} = \qquad - 2\omega u + \eta\frac{\partial^2 v}{\partial z^2}$$

$$\frac{\partial \zeta}{\partial t} = -\int_0^h \frac{\partial u}{\partial x}\,dz$$

$$\zeta = -i\,\zeta_0\,e^{-\gamma x}\,e^{i(\sigma t-\mu x)}$$

$$u = \frac{\sigma}{\sigma^2-4\omega^2}\,g\frac{\zeta_0}{c}\,e^{-\gamma x}(p+i)\left\{C_1e^{(1+i)\beta_1 z} + C_2e^{-(1+i)\beta_1 z} + C_3e^{(1+i)\beta_2 z} + C_4e^{-(1+i)\beta_2 z} - \sigma\right\}e^{i(\sigma t-\mu x)}$$

$$v = i\frac{\sigma}{\sigma^2-4\omega^2}\,g\frac{\zeta_0}{c}\,e^{-\gamma x}(p+i)\left\{-C_1e^{(1+i)\beta_1 z} - C_2e^{-(1+i)\beta_1 z} + C_3e^{(1+i)\beta_2 z} + C_4e^{-(1+i)\beta_2 z} - 2\omega\right\}e^{i(\sigma t-\mu x)}$$

$$\frac{\sigma}{\sigma^2-4\omega^2}\,\frac{g}{c^2}\,(p+i)^2\int_0^h \varphi(z)\,dz = 1$$

$$c = \frac{L}{T} = \frac{\sigma}{\mu};\quad p = \frac{\gamma}{\mu}$$

FIG. 5. HYDRODYNAMIC WAVE EQUATIONS FOR A VISCOUS FLUID ON A ROTATING DISC AND SOLUTIONS.

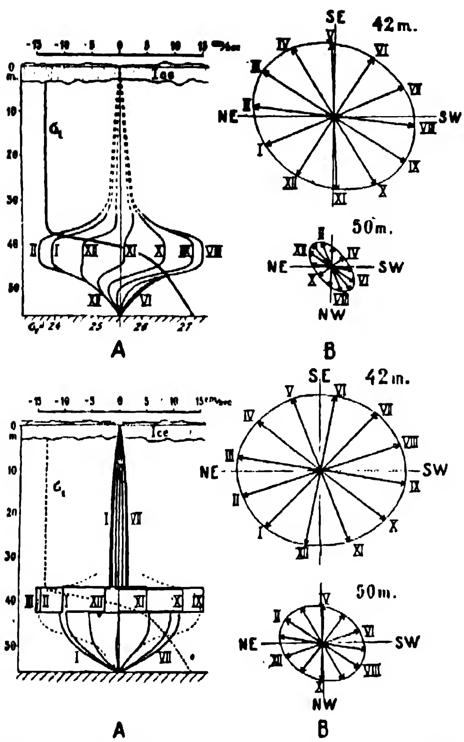


FIG. 6.—OBSERVED TIDAL CURRENTS COMPARED WITH COMPUTED CURRENTS BASED ON THE ASSUMPTION OF EXISTENCE OF THREE LAYERS OF WATER OF DIFFERENT EDDY-VISCOSITY.

water without meeting any resistance, and that the decrease of the currents towards the bottom is due to the resistance along the bottom. Supposing the water to consist of three layers, an upper layer of great eddy-viscosity, a medium layer of no viscosity and a bottom layer of moderate eddy-viscosity, the currents have been computed which are represented in a corresponding way in the lower part of the figure. The computed currents, according to the assumptions, show discontinuous transitions from one layer to another, not occurring in nature, but the general agreement between computed and observed currents is so good that undoubtedly the resistance within the various layers is actually responsible for the character of these peculiar currents. From the theoretical currents the rate with which the range of the tide decreases on account of the resistance can be derived. The result is in close agreement with the observed decrease to which attention has been drawn.

The theory seems to explain all the outstanding features of the tidal phenomena on the north Siberian shelf and may, perhaps, lead to a better understanding of corresponding phenomena on other continental shelves.

As I have mentioned previously, we reached Bering Strait in August, 1925. At that time all of us were sailors. My duties were, for instance, to take care of the navigation of the ship and of the not less important cooking. Previously all of us had taken more or less part in the scientific work. Our cruise in the Arctic finally ended when the *Maud* was lying peacefully anchored off Nome three months ago.

In conclusion, I hope that to-night I have been able to show you a phase of Arctic exploration which differs from the usual geographical exploration, but is of no smaller importance. Our knowledge of the physics of the earth is incomplete so long as data from the Arctic and Antarctic regions are lacking. I hope that this expedition, which went out through the energetic and persistent efforts of Captain Roald Amundsen, may bring results which will fill a few gaps. However, we have traversed only a small region and have left many problems unsolved. The field for future exploration is tremendous. I hope that this, which I may call physical exploration of the Arctic, will continue for a long time after the completion of the map of the Arctic region and after the discovery of the last island.

RADIO TALKS FROM THE HARVARD OBSERVATORY[1]

THE AMATEUR'S WORK IN ASTRONOMY

By LEON CAMPBELL
HARVARD COLLEGE OBSERVATORY

TO-NIGHT I shall assume that there are some among the radio listeners who are interested not only in what amateur astronomers have done in the past, but also in what they themselves might be able to do to increase their own knowledge of astronomy and help to add to the sum total of scientific information. The word amateur implies one who works for love; and if ever one works purely for the love of the thing, it is in astronomy that he can find an inspiration. And at this point let me say that unless you have had special preparation for the work, astronomy should be your avocation rather than your vocation. There is much that has been done in the past by the amateur astronomer, and I can assure you that still more remains to be done which will greatly augment our knowledge of the stars.

History records many instances in which the amateur has made noteworthy contributions to astronomy, probably more than in any other branch of science. Dr. Henry Draper's contributions to the study of stellar spectra may be cited as a remarkable example. The continuation of his pioneer work was made possible at the Harvard Observatory through the interest and generosity of Mrs. Draper after the death of her husband.

Another notable example of such efforts on the part of an American amateur astronomer is recalled in the case of the late Dr. Joel H. Metcalf, who not only constructed with his own hands the several telescopes which he used in his investigations, but manipulated them with marked success in the discovery of new asteroids and comets. Here was a real genius who, purely for the love of science, made lenses which were second to none and used them with the skill of a well-trained professional astronomer. The Harvard Observatory has several photographic telescopes equipped with Metcalf's lenses, which are being used regularly for astronomical work.

It is all too true that many an enthusiast has invested his cash in a fairly good telescope, amused himself with peeps at sun, moon, planets, stars, and perhaps at a visiting comet, and then, after airing his astronomical knowledge to his friends, has relegated the instrument to the attic. One who has made such desultory observations has only just begun to enjoy the pleasures of the telescope.

You ask, then, what one can do in the observational field to make a real contribution to our knowledge of the science. There are several fields of research open to the amateur with or without a telescope.

[1] These three radio talks from the Harvard Observatory are taken from a series of twenty-two recently broadcast from station WEEI, Boston. The talks will be collected into an illustrated book, "The Universe of Stars," to be published by the Harvard Observatory.

For the observer without a telescope, meteor observing offers a rich field of endeavor. When one realizes that millions of meteors enter the earth's atmosphere daily, some of them no larger than grains of sand, others large enough to light up the heavens even in broad daylight—as evidenced by the daylight meteor of the morning of November 15, 1925—one perceives that there is plenty of work to be done in observing meteors; in counting them, in gauging their positions, and in estimating their brightness, especially during the occurrence of meteor showers.

If one watches any selected area of the sky on almost any clear night for, say, half an hour, he will doubtless be able to count several conspicuous meteors, and with little more than a passing knowledge of celestial topography, he can plot their paths, and thus furnish data for determining their radiants—the points in the sky from which the meteors appear to originate.

The American Meteor Society, under the direction of Professor C. P. Oliver, at the Leander McCormick Observatory, Charlottesville, Va., has gathered together a group of meteor observers in this country, and new recruits to the ranks are constantly being secured. The work is easy, fascinating and productive of real results.

Dr. Fisher, in his forthcoming talk on shooting stars, lays particular stress on the use of photography in securing valuable data on meteors. While this sort of work can not be expected to supersede visual observations, it is obvious that when a meteor trail is photographed, much more information can be obtained, owing to the fact that the photograph is a permanent record.

There is still another field which is open to the amateur who does not possess a telescope. You have all heard at one time or another about new stars, or novae, as they are generally called. Since the time of Tycho Brahe about fifty new stars have been discovered, and nearly a dozen of these have been first detected and later extensively observed with the unaided eye.

Tycho Brahe's nova, which appeared in the year 1572 in the well-known constellation of Cassiopeia, became as brilliant as the resplendent planet Venus at her brightest, and remained visible to the naked eye for many months. Several interesting novae have appeared in the heavens during the past twenty-five years, beginning with the brilliant Nova Persei in 1901. This was followed by Nova Geminorum in 1912, Nova Aquilae in 1915, and Nova Cygni in 1920. The most recent instance is that of the new star which appeared in May, 1925, in the southern constellation Pictor. Unfortunately for us northerners, it was visible only in the southern hemisphere. This star reached the first magnitude on June 9, and remained visible to the unaided eye for many months, undergoing numerous irregularities in brilliancy.

As an instance of amateur aid to science, it is of interest to note that all the bright new stars which have appeared in the present century were first detected by amateurs—amateurs whose familiarity with the brighter stars of the conspicuous constellations enabled them to detect the presence of a strange star early in its spectacular career. The Rev. T. D. Anderson, of Edinburgh, Scotland, is an independent discoverer of at least three new stars, being the original discoverer of Nova Aurigae, in 1892, and of Nova Persei, in 1901. Mr. Richard Watson, of South Africa, was not only the first to see the recent nova in Pictor, but was one of the very first to see Nova Aquilae on June 8, 1918. This latter nova was discovered independently by more than a score of observers, the majority of them being amateurs. Since most of the novae occur near the Milky Way, it might well be worth while for the amateur to familiarize himself with all the naked eye stars of the constella-

tions which lie along this well-known band of stars.

And now for the work to which the proud and fortunate possessor of a telescope may devote his leisure moments. From earliest times comet seeking has proved an alluring diversion for both professional and amateur. Although in recent years many comets have been picked up from photographic plates in the hands of the professional, a large number have also been found by amateurs as the result of a definite search. The comet recently discovered in Boötes, first seen by Mr. L. C. Peltier, of Delphos, Ohio, an amateur observer of variable stars, was found by him several days before it was seen by any professional. Mr. Peltier, in his nine years devoted to astronomical observing, has found three comets, although only the last one proved to be an original discovery. The late Mr. William R. Brooks, of Geneva, N. Y., was the original discoverer of at least a dozen comets in some twenty years of observing.

A telescope of short focus and large field, with a low power eyepiece, is best suited to comet seeking, and if a comet becomes as bright as the ninth magnitude it will rarely fail to be detected. Although the discovery of comets may lead to considerable publicity, with even an occasional comet medal for new ones, the work is of far less importance to astronomical science than the branch of observing I shall mention next—the observing of variable stars.

The better to explain this variable star work, let me tell you something about one of the most enthusiastic bands of amateur observers that can be found in this country—the society known as the American Association of Variable Star Observers, and called for short the "AAVSO." It is composed mainly of amateurs, and its chief purpose is to secure those observations that will be of the greatest value to the professional astronomer. During fourteen years of persistent endeavor on the part of nearly three hundred observers, the association has accumulated over two hundred thousand visual observations.

With active observers in all walks of life, from the surgeon who uses an eight-inch reflecting telescope of his own make, and the farmer's son who operates a six-inch refractor loaned him by a sympathetic observatory, to the busy housewife who carries out her small glass each clear night to study the stars, the personnel of the society is truly representative and widely varied.

With numerous telescopes at their disposal, ranging in size from less than three inches to more than twenty inches in aperture, observers follow systematically the regular and irregular variations in the light of nearly five hundred stars. Not only are observations made regularly by members situated in nearly every section of the United States, but a chain of observers now encircles the globe, with contributors from Europe, South Africa, Australia, India and Japan. So completely is this work now carried on that professional astronomers rely almost entirely on the results of these amateur observers for the fundamental data necessary to a better knowledge of the causes underlying the variations.

Many of the stars which are being so carefully observed by the "AAVSO" are the so-called long period variables, about which Miss Cannon speaks in her chapter on variable stars. Their variations are usually gradual, and they occupy several months in passing from maximum to minimum magnitude. A star may be of naked-eye brilliance tonight, and four or five months hence we may require the aid of a moderately large telescope in order to see it.

A notable example of such a star is Mira Ceti, the "Wonderful," in the constellation of Cetus, the Whale. It is now (December, 1925) near maximum brightness, and clearly visible to the un-

aided eye. This was the first variable star ever discovered, and for over three hundred years its light variations have been closely watched by succeeding generations of astronomers, professional as well as amateur. About every eleven months it reaches maximum brilliancy, being sometimes as bright as the Pole star, at other times not much brighter than the fourth magnitude. It is readily recognized when bright, by its reddish color, and the recent observations by amateurs indicate that its last rise from minimum to maximum occupied about two months, the rate of increase at one time exceeding a magnitude in ten days.

Not only are the several hundred long period variables well looked after by the amateur observers, but their working lists contain some very peculiar "irregular" variables, made the more interesting by the fact that we never know exactly what they will do next. Numerous examples could be cited, but I shall pick out only a few typical cases to give you an idea of the whims and vagaries which they present. Take the case of SS Cygni—a variable star discovered at Harvard in 1891 in the constellation Cygnus, the Swan. Here we have a fairly faint star, usually about the twelfth magnitude, which at intervals all the way from twenty to ninety days suddenly brightens up nearly a hundredfold, almost reaching the eighth magnitude. The time of the star's rise to maximum is unpredictable, and also the speed with which it increases in light intensity is variable. To-night it may be barely visible in a four-inch telescope, and to-morrow night it may be at full brightness, so brilliant, in fact, that it stands out as the brightest star in the field of view in the telescope. At other times the star may have started on its increase, and instead of accomplishing it in a night or two, it may consume a week or more in attaining its maximum. Is it any wonder that scores of amateurs vie with one another to be the first to catch SS Cygni on its rise to maximum? There are several other stars which possess this fitful type of variation, but SS Cygni has proved the most popular with observers.

An example of still another type of variable, that has greatly interested the members of the "AAVSO," is SU Tauri, a faint star which lies in the constellation of the Bull. This star, discovered to be variable at Harvard about twenty years ago, presents features quite distinct from those found in SS Cygni. In SU Tauri we have a star which for a long time remains at normal maximum brightness, about magnitude 9.5, and then without warning suddenly diminishes to nearly a hundredth part of its original intensity, becoming so faint, indeed, that only those observers with the more powerful telescopes can see it. A little over a year ago the star passed through one of its spasmodic drops to minimum, after having remained bright for seven years. In fact it changed so little in those seven years that some of the observers wondered if they had not been observing the wrong star, because in the field of such faint stars a wrong identification is easily possible. At the present time (December, 1925) the star is again on the wane, the Harvard Observatory having been first notified to this effect by an amateur in Ohio.

I could describe at greater length the vagaries of numerous irregular variables, but enough has been said to indicate some of the thrills to be expected when one has become an experienced variable star observer. The work is not difficult. It requires considerable perseverance and patience, and a readiness in identifying stellar configurations, whether in the sky or the telescope. The "AAVSO" supplies its members with charts, instructions and report blanks, and if you are interested, I suggest that you write to the Harvard Observatory, or to the Secretary of the Association,

Wm. Tyler Olcott, 62 Church Street, Norwich, Connecticut.

All the observations made by members of this Association of Variable Star Observers are communicated monthly to the Harvard Observatory, where they are plotted and indexed, and later discussed in considerable detail. The original observations are published regularly in *Popular Astronomy.* The amount of data so far compiled by members of the association, if bound together in one volume, would fill over a thousand pages—a notable contribution to astronomical science by amateurs. The "AAVSO" is one of the largest of such organizations. There are similar associations in England, France, Russia and elsewhere.

Now that I have attempted to tell you what you can do to increase your own interest in the stars, the rest remains with you. For over a quarter of a century Harvard Observatory has aimed to instill into the mind of the serious amateur a desire to produce results that are of value to astronomy. It has become the center for such information in this country, and even foreign astronomical associations are constantly seeking its aid, and in turn contributing their own observations for discussion. A closer relation between amateur and professional will doubtless tend towards a more widespread interest in astronomy, and both astronomer and amateur will benefit by the contact and cooperation.

CLUSTERS AND NEBULAE

By Professor SOLON I. BAILEY
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Five or six thousand stars are visible in the whole sky to the average eye. Only a few of them, however, are at all conspicuous, and although they are found scattered over the entire heavens, their distribution is by no means uniform. Stars have a gregarious tendency. As mankind is grouped into families, and many families make up a nation, so the stars in many cases are grouped into clusters, and these aggregations, together with numbers of individual stars, make up our sidereal systems.

As an example of the numerous irregular clusters, we may take the well-known group of fairly bright stars called the Pleiades. Six stars can be seen easily with the naked eye, a seventh star is discerned without much difficulty, and ten or twelve stars can be detected by an exceptionally good eye under favorable conditions.

Near the Arequipa branch of the Harvard Observatory in Peru, a partially extinct volcano, El Misti, rises nineteen thousand feet above sea-level. The position of the mountain is to the northeast of the observatory, and precisely at such an angle that the Pleiades when rising seem to be resting on the summit of the volcano. In the hazy light they appear to the startled vision as a flaming torch, and might be mistaken at first glance for an eruption of the volcano.

In ancient times this cluster was universally regarded as a group of seven stars. The seventh and faintest was perhaps brighter at that time than it is now, and much romance and poetry have been associated with the so-called lost Pleiad. The number seven has long been looked upon as a perfect number, and perhaps this may account in part for the extraordinary regard in which the cluster has been held in all ages. The stars of the group have been worshipped by various peoples of antiquity, and splendid temples have been erected in their honor.

Olcott has collected a large number of traditions in regard to the Pleiades. Thousands of years ago the Chinese worshipped them as the Seven Sisters of Industry, and at the present time they are often referred to as the Seven Sisters.

Many other names have been given to the Pleiades. In Greek mythology they were the daughters of Atlas, and the seventh daughter made herself invisible from shame, having had a mortal lover, while all her sisters had divine lovers. Another myth explains the cluster as an act of the gods. According to this story the Pleiades were the maiden companions of Diana, and were pursued by Orion. In answer to their prayer for aid, they were changed into a flock of doves and placed among the stars. By others of less imagination than the Greeks, the Pleiades were regarded as a hen and her chickens.

In many countries the rising and setting of the Pleiades have been used for marking such events as plowing and planting, and their influence has been considered favorable to rainfall. The literature of all ages contains reference to this cluster. We read in Job, "Canst thou bind the sweet influences of Pleiades?", perhaps referring to the power they were supposed to have in making the change from winter's cold to the joys of spring.

With the invention of the telescope, the number of stars recognized in the Pleiades cluster was greatly increased. The number that can be photographed with a large telescope is several thousands, but the great majority of them are faint and do not belong to the cluster. It is, however, a somewhat surprising fact that the number of such faint stars is actually less in the region than in the area immediately surrounding it. This is perhaps due to the fact that a faintly luminous nebulosity pervades the cluster and cuts off some of the light of the stars that are situated beyond it.

The Pleiades are not merely the accidental projection on the sky of a number of unrelated stars, but they form a real family group, the different members of which have similar characteristics, and a common motion in space. The real number of stars in the cluster is only a few hundreds, while many thousands which appear to be in the same region lie far beyond.

Many irregular clusters are found in different parts of the sky, nearly all in or near the plane of the Milky Way. In fact the Milky Way is largely made up of such clusters. Some clusters are not apparent to the eye as such, but are found to be real groups from their common characteristics and motions. If our sun were a member of such a group, this might not be apparent to an observer on the earth. The sun is so near that it appears to us as a unique world, the king of all celestial luminaries. It is difficult to appreciate the fact that it is merely one of the stars.

A star has been defined as "a huge mass of matter held together by its own gravitation, kept from collapsing by a very high internal temperature, and engaged in the business of generating heat in its interior." Many stars occur as single individuals, like our sun. A very large number of double stars is also found. A celestial birth results in twins in about one third of all cases known. A few triple and quadruple stars also occur. Apparently stars are formed in nature's laboratories from an original gaseous mass, which may remain single or develop into two, or rarely into several stars.

No reference is made in these remarks to planets like our earth. Our sun as a star is single, but it has many planets revolving about it. Whether other stars have planets we do not know, but it is more than probable that among the millions of stars which exist in our stellar system alone, at least a few are accom-

panied by planets, although we may never be able to see them. If the solar planets have been caused by the close approach to our sun of another star, causing a disruption of the sun's mass, it is evident that, given time enough, other such approaches of one star to another are inevitable.

No relation appears to exist between double stars and clusters; that is, the cluster is by no means a further development of double and multiple stars. A cluster, even a small one, represents a grouping of a considerable number of individuals, which may be single or double. The number of stars in a cluster may be few, or it may be many thousands. Many of the open clusters, which have been observed and catalogued, are simply dense aggregations of the stars which make up the Milky Way.

There is, however, a different type known as the Globular Cluster. These clusters have the form of a globe, but nevertheless they often display a decided tendency to ellipticity. About one hundred such clusters have been found, and the number now appears to be about complete. It is doubtful whether an increase in the power of telescopes will reveal many new globular clusters. Some of these clusters are visible to the naked eye as rather faint and hazy stars.

One of the most interesting of globular systems is the great cluster in Hercules, which appears to the unaided eye as a single hazy star of about the sixth magnitude. Seen in the telescope this object takes on the appearance of a brilliant ball, made up of countless points of light, each one a star. The stars appear to be closely packed together and extremely condensed at the center. Although in reality they do form a distinct, dense system of related stars, the apparent extreme proximity of the individuals to each other is due in part to the vast distance of the cluster. Shapley has determined the distance of this cluster from the earth as about thirty-five thousand light years. So that if we could be placed on some imaginary planet circling around one of the central stars of the system, that particular star would be seen as our sun, and all the others as stars, many indeed of great brilliancy. The appearance of the sky would be very different from that with which we are familiar.

The globular cluster in Hercules contains at least thirty-five thousand stars which can be photographed to-day, and it is probable that the real number is not much less than a million; other globular clusters are equally vast, and many are far more distant.

A very interesting feature of the globular clusters is the presence in some of them of a large number of variable stars. These stars are variables of the Cepheid type, and are remarkable for the uniformity of their periods, their ranges of variation, and their brightness. Owing to the great distance of these clusters, the apparent magnitude of the variables, which are among the brightest stars in the clusters, is very faint, so that a large telescope is necessary for visual observations. They are best studied on photographs, since the eye is easily tired by the dazzling light of such a multitude of close stars, when they are viewed in the telescope.

Messier 3, a faint but wonderful globular cluster in the northern constellation Canes Venatici, gives a good example of such stars, for one in seven among the brightest stars of the cluster is variable. At maximum the light is somewhat fainter than the fourteenth magnitude, and at minimum it is fainter than the sixteenth magnitude. The whole period of variation from one light-maximum to the next is about thirteen hours, and, in many cases, the changes appear to go on with perfect regularity through many thousands of oscillations. The stars might be called nature's celestial timekeepers, and would serve, if needed, as admirable watches. If a photograph of

this cluster had been buried with King Tut Ankh Amen, it might be made to reveal, from a study of these variable stars, the exact epoch when the photograph was made.

The Cepheids have been used by Shapley as one means of determining the distance of the globular clusters and indirectly the size of the stellar system. If we accept his conclusions, these clusters, although vast and semi-independent, are found to be, in general, within the confines of the galactic system and in close relation to it at the present time.

So far we have been speaking only of stars. There is, however, a very different class of celestial objects known as nebulae. These are of many kinds, but in most cases, if not in all, they are so vast that even the largest star shrinks almost to a point in comparison. They have been divided into the galactic and non-galactic nebulae, that is, those which occur in the Milky Way, and those which show a distinct avoidance of the Milky Way. Under the first division we have the more or less luminous material such as is seen in the well-known Orion Nebula. This nebula is shown by the spectroscope to be of a gaseous nature.

In the early days of the telescope, many objects which had appeared nebulous to the naked eye, or in a small telescope, were later shown to be really clusters of stars. It was natural, therefore, to assume that all nebulae could be resolved into stars, provided a sufficiently large telescope were used. It was at this time that the Harvard Observatory obtained the fifteen-inch refractor, then the most effective telescope in use. One of the early astronomers of the observatory, in testing the resolving power of the new telescope, was convinced that he had partially resolved the Orion Nebula into stars and announced his observation. We now know by the spectroscope that this and many other nebulae are from their very nature not resolvable.

It will be remembered that the diameter of that star we call the sun is considerably less than a million miles, and that the diameter of even the greatest star known is not more than a few hundred millions of miles. The diameter of such nebulous objects as that in Orion is so vast that it can not be expressed conveniently in miles. This nebula is at a distance from us of perhaps six or seven hundred light years, and the diameter of the brightest central part is five or six light years, or from thirty to forty millions of millions of miles. The faintest extensions of the nebula are several times as great. Many other bright nebulae of great size are found along the Milky Way.

In addition to these irregular luminous nebulae, there are also found in the Milky Way extensive areas which are filled with faintly luminous or entirely dark obscuring clouds. There are also the so-called planetary nebulae.

Of the non-galactic nebulae several varieties are known, which occur in great numbers. The real nature of many of these nebulae is still a mystery. The spectroscope shows that, for the most part, they are not gaseous.

The spiral type of non-galactic nebulae is of great interest. They are not nebulae except in name, since it has been shown recently that many of them are composed chiefly of stars. Perhaps the most striking example of these objects is the great spiral in Andromeda, which is faintly visible to the naked eye. On photographs with long exposure, made with great telescopes, it stands revealed as a marvelous stellar system. Recent studies indicate that this system is a so-called independent universe, at a distance of about a million light years, and hence far beyond the limits of our galactic system or local universe. Its longest diameter must therefore be many thousands of light years. It is a vaster stellar system than our own was believed to be by astronomers of a preceding generation, though now we know our own system much exceeds it in size. Many of the nebulous aggregations in this

spiral have been resolved into stars by the 100-inch telescope on Mount Wilson. Doubtless it also contains many real nebulae, such as abound in our own galactic system. Thousands of spiral nebulae exist in the sky, and many of them must be at even greater distances than the great spiral in Andromeda.

In addition to the spirals, other nebulous objects are found in the non-galactic sky. Many are globular or elliptical in form, and appear, even in the greatest telescopes, to be structureless. They are too difficult for interpretation at the present time. It should be noted, however, that if the statements so far presented in regard to the non-galactic nebulae are correct, there is no obvious explanation of the fact that they appear to avoid so persistently the plane of the Galaxy. It is possible that they do not really avoid this plane, but that, though present, they are concealed from our view by the dark obscuring clouds to which reference has already been made.

We see, therefore, that the universe is composed of a great number of semi-independent systems of stars and nebulae, of which our own galactic system is only one, though perhaps the most important. We are speaking, of course, of the visible universe; when we attempt to go beyond that, we leave the realm of exact science and enter a realm of theory and speculation which appears as boundless as the universe itself.

STELLAR EVOLUTION

By CECILIA H. PAYNE
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Once more I am going to take you out among the stars and ask you to consider the grandest process known to man. Again and again, in this series of radio talks, you have heard tales of change and development. You have been told of the meteors, which travel through the cold regions of space as hard lumps of stone, and burn up and perish as they rush into our atmosphere. You have heard how the comets, the wanderers of the solar system, show signs of wear and tear and may end up at last in a shower of meteors. You were reminded that all the planets were born from the atmosphere of the sun, and set out in elongated orbits on their journeys around their parent as masses of glowing gas, only to settle down into the nearly circular orbits they pursue to-day, cooling off into the solid bodies that we know. All this has happened in a period of time that can be measured; a matter of a few thousand million years. And again you heard of changes that have passed over the surface of the earth, from the time when it was torn from its parent, the sun, down to the present day. Change and development are writ large upon the solar system.

My title to-night is "Stellar Evolution." I am to tell the story of the development of the stars—a story that puts the greatest of strains on the human imagination. Is it possible that the stars develop? That they are born and run their course and die? For hundreds of centuries man has watched the sky, and to his crude apprehension the face of the heavens seems to be so unchanging that we sometimes speak of the "eternal stars." But that impression is a result of human finitude, and astronomy is now expanding our outlook. Astronomers observe the sky and tell us that the stars are altering their positions, moving across the expanses of space. Although some stars greatly ex-

ceed our common earthly velocities, they are so far away that their motion across the sky would hardly be noticed by the casual observer.

In the same way we are sure that the stars go through a vast process of development, but it takes place so slowly that it can not be directly observed. The span of human life does not give us time to notice the development of an ordinary star, and, indeed, the whole duration of living things on the earth has not seen an appreciable change in the light of the sun.

Yet we believe that stars are born, and live their lives, and die; I have only time to touch very lightly on the reasons that form the basis of our belief. The main foundations of the theory of stellar evolution are the facts that the stars exist, that they shine, and that they differ among themselves. I shall try, in a few words, to show that each of these facts has a bearing on the theory of the evolution of stars.

When we look at the twinkling light of the stars, we need all our powers of imagination to visualize what they really are. Every star is an enormous mass of glowing gas. We might suppose that a mass of this kind would have a tendency to spread out and dissipate entirely. The existence of isolated stars would then be difficult to understand. But a star is made of matter and therefore all its parts are under the pull of gravitation. The pull of the enormous mass of which the star is composed keeps it together—for every part is attracted towards the center of the star.

Another difficulty arises at this point. If a star is being pulled towards the center, and if, not being solid, it has no rigidity to resist the pull, why does it not collapse altogether? How does it continue to exist as an expanded gas? The answer is that there are other forces holding the star out; mainly the pressure of the heat and light that are pouring out from the inside—a pressure large enough to keep the star blown out like a balloon. Of course, the star is not hollow like a balloon. Probably it gets denser and denser, the further we go into the interior. But we may picture every part of it as held out from within by the pressure of light and heat, and held in by the pull of gravitation. We can thus see, in a rough way, how it is possible for a star to exist—gravitation prevents spreading out into space, and light pressure prevents collapse. Indeed it is the outpouring of light from within that makes the stars what they are; but, as we shall see, this same reckless expenditure of energy also prevents them from surviving without change.

The radiation that keeps the star expanded is used up in the process and never gets out to the surface at all; but enormous quantities of heat and light do get out, as we know, because it is by their means that we perceive the star. This very light and heat that we see are the seeds of the star's ultimate destruction. The escaping light and heat are a dead loss to the star, diminishing its power to radiate, and its capacity to keep itself blown up under the pull of gravitation.

Unless a star is able to compensate matters in some way, its output of light and heat will alter, because the supply is being exhausted. The star will of necessity change in some way that can be observed, growing fainter at a rate that can easily be predicted. Therefore it is certain that the stars must change, just because they shine; either they must alter on the surface in some way that we can observe, and at a perfectly definite rate, or they must alter inside in a way that will compensate for their loss of heat and light into space.

We feel sure, then, that every star is liable to change. A further reason for believing in stellar evolution is that the stars are not all similar; they differ

among themselves in all kinds of ways. I have not time to describe the variety that we find in the composition of starlight, but I must say a few words on the differences that the stars display in size and brightness.

It is a matter of common observation that the stars that we see in the sky seem to have different brightnesses, and probably many of us have noticed that they have different colors as well. Of course, from the earth, it is impossible to get a fair idea of the stars by merely looking at the sky, because some of those that appear bright to us only show up because they are fairly close; and, on the other hand, a really bright star may be so far away that it looks faint in the sky.

To give all the stars a fair chance we ought to put them all at the same distance, and if we could do that, we should see a most varied array. There would be stars of all brightnesses, and of all colors from blue-white to dull red (which means all temperatures from forty thousand degrees centigrade to three thousand degrees). The sun would not stand out conspicuously. Some stars would appear ten thousand times as bright as our sun, and the faintest star known would be about ten thousand times fainter. Another thing that would be noticed if the stars were brought near enough to be seen as spheres instead of mere points of light is the difference in size. The smallest normal star known would have about half the diameter of the sun, but some of the typical larger ones are so enormous that if they were to be placed where the sun is now, the earth would be well inside them.

We are faced, then, with a most varied collection of stars, and forced to ask the question: How do they happen to be that way? Are they all differently constructed? Are the differences I have just described the result of being made differently? Or are all the stars essentially the same, only in various stages of development? The evidence is rather convincing that they are all in different stages of development, and that the variety is not a matter of different composition.

I shall not attempt to suggest to you the ideas that have led us to our present beliefs on the subject of stellar evolution, but instead I shall describe, very briefly, an ordinary, typical stellar life-history.

We do not pretend to go back to the beginning; the first stage in our stellar life-history shows the young stars as very diffuse globes of gas, at a temperature of about three thousand (3,000) degrees and shining with light of a reddish color. In fact they are already stars. (I do not apologize for not taking you further back, for my subject is the development of stars, and not their origin.)

Some of the most diffuse and coolest stars, the very youngest known, seem to vary in brightness, and behave as if they had some sort of instability; and it may be that this variability has some connection with their extreme youth. The diffuse, cool stars have an enormous output of light and heat, because they have a large surface, and there is plenty of opportunity for the energy to escape. But in spite of the outpouring of energy, a young star proceeds to grow hotter, and at the same time it grows both smaller and denser. These young "giants" have a great internal supply of energy, on which they draw, not only making up for the flood of light that they are giving out, but raising their own surface temperatures more than tenfold. The temperature of the outside rises from three thousand to forty thousand degrees centigrade, while the temperature of the inside rises still more.

At the beginning of its development, a young star probably has a central temperature of less than ten million degrees centigrade, but by the time the outside has gone up to ten times the original surface temperature, the inside is believed to be at about thirty million degrees. All the time the star is growing hotter, it shrinks in size and grows denser. And all the while it continues to pour out heat and light, losing energy into space at an enormous rate, a rate depending on its size, its temperature and other things.

If the outside of a star has risen to a temperature of forty thousand degrees or thereabouts, it has apparently grown as hot as the make-up of a star allows. Few stars attain to such heights, and indeed many are probably unable to exceed fifteen thousand degrees in surface temperature. The precise temperature that is reached seems to depend upon the amount of material in the star, being greater for heavier stars. Stars that have risen to their maximum temperature begin to decline again, growing cooler at the surface, changing back again from the blue-white stage that they reached in their prime, through white, yellow and orange to red. They still go on shrinking in size and growing denser as they cool; they have now arrived at the stage where we call them "dwarfs." The giants are the diffuse stars that are growing hotter, and the dwarfs are stars that are getting cooler.

But they are only cooling on the outside. Inside, the temperature remains high, and the outside only cools off because the body of the star is becoming less and less transparent to heat as it grows denser. At last we may picture the star cooled off, at the outside, to the same temperature at which we first saw it, but it is now a very different object. In the beginning it was three hundred times the size of the sun; now it is, perhaps, one fourth of the sun's size. It has poured out vast quantities of heat and light into space—quantities that can be measured in millions of millions of millions of millions of tons.

Finally we may suppose the star to grow still cooler; the outside becomes more and more opaque to radiation, and the star gets fainter and fainter, until it is altogether invisible. There is still a great mass of matter, but the outpouring of energy that gave it a place among the stars is at an end—the star has reached the term of its career.

The youth of a star, the brilliant giant stage with the mighty output and the rising temperature, is relatively short. But the way down, it seems, is long and slow, for the star continues to produce, within itself, enough heat to retard the cooling process very greatly, especially when the body of the star becomes increasingly opaque to radiation, so that the supply that escapes to the outside is much reduced.

This internal production of energy is one of the large problems of modern astronomy. Where does the energy come from? What keeps the stars going? Once astronomers believed that a star could produce, by its own contraction, enough energy to supply it with the necessary heat. But now we believe that the progress of a star's development is so slow that the story I have told you takes about a thousand million million (1,000,000,000,000,000) years to enact. The amount of energy that a star could produce by merely contracting would be too ridiculously small to keep it going for so long a time. And at present it is the belief of the astronomer that the stars keep themselves alive by consuming their own substance. The energy that keeps them going is derived, at the enormous temperature of several million degrees, from the nuclei of the atoms at their centers. The energy that the stars are pouring into space is literally a part of themselves; in giving out

light they radiate their own substance away.

I have had a very short time in which to describe to you the longest and most solemn process known to man. I have said with some confidence that the stars do develop, but it can be said with equal certainty that we are very ignorant about the stages of the development and about its causes. There are many things that are very hard to account for, and I have not even mentioned them.

In conclusion I will, however, speak of one interesting and puzzling matter. We might have expected that, given similar conditions and laws, if all the stars had the same start, they would all by this time have got to the same stage of development. But obviously they are all at different stages of development; and, curiously enough, it is this variety that first led us to infer that they develop at all. There are some young stars and some old stars (often even in close association with one another) and some of them must have started before others, unless the life of a star is to be measured in other dimensions than the lapse of time.

In fact, all that I have said so far describes a process of "running down," slow and majestic, but a running down all the same; but the present state of the universe does not point to a universal "run-down condition." This makes us think that there may be some cyclical process at work, giving a new start to the stuff the old stars were made of; and that perhaps the stars may be eternal after all.

THE STORY OF TIMEKEEPING[1]

By CARL W. MITMAN

U. S. NATIONAL MUSEUM

FROM studies of early man and his customs it is known that he began the day at sunrise and divided it into twenty-four hours. It is further generally recognized that the varying length of shadows caused by the sun suggested the first means of indicating the hours. Man spent many thousands of years on this earth, however, before any device was manufactured for telling time by the sun; in fact, the invention of the sundial is generally accredited to a Greek, named Berosus, who lived about 550 B.C. Before that time it is more than likely that some natural high-standing object like a single tree or a precipice was depended upon to indicate shadow lengths and the passage of time.

The value of Berosus's invention was apparently soon recognized and sundials were erected quite numerously, especially in public places. They were not, however, always gratefully received, as is indicated in the following dirge, if I might call it that, of an old dyed-in-the wool Roman conservative:

The gods confound the man who first found out
How to distinguish hours! Confound them too,
Who in this place set up a sundial,
To cut and hack my days so wretchedly
Into small portions! When I was a boy
My belly was my sundial; one more sure,
Truer and more exact than any of them.
This dial told me when 'twas proper time
To go to dinner (when I had aught to eat),
But nowadays, why . . .
I can't fall to unless the sun give leave.
The town's so full of these confounded dials
The greatest part of its inhabitants,
Shrunk with hunger, creep along the streets.

[1] Smithsonian Radio Talks, arranged by Mr. Austin H. Clark, broadcast from Station WRC.

His grumbling, however, had no permanent effect, and sundials remained one of the main methods of telling time for fully fifteen hundred years after the fall of Rome.

At first man led rather a simple life and the fact that a sundial could not indicate time on cloudy days or at night was of little importance, but the time did come when it was felt that this shortcoming should be remedied and it fell to the lot of some unknown inventor to devise the waterclock. How it came about that water was put to work to measure time is not known, except that the idea was hit upon probably because of the ease with which a uniform flow of water could be maintained, and, of course, to obtain uniform motion for an infinite length of time is the ideal toward which the makers of timepieces are still striving. Fundamentally, the action of waterclocks depended upon the flow of water through an opening, and there were two types, one indicating hours of varying length, and the more modern instrument, used as late as the eighteenth century when hours of equal length were measured. The ancient one in its simplest form consisted of a thin metal bowl, about five inches in diameter, with a small hole in the bottom. This was placed on the surface of a basin of water and a boy was detailed to watch it. At first it would float, but gradually as the water oozed up through the hole the bowl filled and sank. The instant this happened the boy struck a gong, fished out the bowl, emptied it and placed it on the surface of the water for the next

round. The more modern one was developed as a result of man's increased knowledge of mechanical principles and had incorporated in it many mechanical movements which were put in motion by the flow of water. None of these waterclocks indicated time by a dial and hands but usually by periodically striking gongs in some ingenious way.

Thus the waterclock supplemented the sundial, but inasmuch as water would freeze in winter there was still a need of some new device to supplement both the sundial and waterclock. This resulted in the invention of the sandglass, which is so familiar to all of you that no time need be taken up to describe it.

Besides these chief means of indicating time there were a number of other methods used locally throughout the world. The Chinese are said to have tied a length of rope into knots, spaced equally apart. One end of the rope was set on fire and as the fire crept to a knot a gong was struck successively until the whole rope was consumed. King Arthur of England devised a time indicator composed of six candles, each twelve inches long, which burned at the rate of twenty minutes an inch. Thus one candle lasted four hours, and six, twenty-four hours. His scheme worked all right as long as the wind did not blow, and to shield the flame from the wind he had cases made of horn, scraped very thin, which were slipped over the candles. In old English this case was called a "lanthorn" and from it we get our word "lantern."

A weight-driven clock was the next great step in timekeeping. There are differences of opinion as to who invented it, but it is generally considered that the clock which was made and installed in Glastonbury Abbey in England, by a monk named Peter Lightfoot in 1336, is the closest approach to a weight-driven clock in the modern sense of the word. This clock movement is still in existence and is exhibited in the New Science Museum in London. Of course it is a rather crude-looking affair, but the wonderful part about it is that it possesses all the important features still in use in weight-driven clocks except the pendulum, minute and second hands.

For the next one hundred and fifty years mechanical craftsmen in Europe devoted their every effort to making clocks. Each passing year saw them increasing in numbers, decreasing in size and improving in accuracy, but without any fundamental change in mechanism. Instead the craftsman confined his ingenuity to producing beautiful cases and indicating time by automatons rather than the simple dial and hand. By incorporating additional mechanism the clocks, besides telling time, were made to indicate the movements of the sun, moon and stars, and the passing of the days, months and years.

The story is told of a Frenchman, named Burdeau, who made an ingenious clock in compliment to Louis XIV, in which there was represented, sitting on his throne, Louis surrounded by all the pomp of royalty and the princes and dukes of Italy and the electors of the German states. These individual figures advanced toward the king and, after bowing, would strike the quarters of the hour with their canes. There were other figures representing the kings of Europe and these, after paying their respects to the king, struck the hours with their canes. Burdeau was prevailed upon to publicly exhibit his clock and after he had decided to do so he made a change in the movement which he thought would be highly pleasing to his king. He knew of the stubborn and unyielding attitude of King William III of England toward Louis, and the change in his clock was to cause the figure representing William to make a most extreme bow when he appeared. When the exhibition took place and King William appeared, he bowed very low but at the same instant something went wrong with the mechanism and King Louis fell out of

his throne prostrate at the feet of the British king. The news of this accident spread very rapidly and was considered a bad omen, so much so that when King Louis heard of it he had Burdeau sent to the Bastille.

There can be no doubt that the presence of portable sandglasses acted as an incentive to these old clockmakers to make a portable clock or even a pocket timepiece which could be carried around as easily as a ring sundial. The portable clock came about in a comparatively short time, but it was not until 1500 that the watch was born, when Peter Henlein, of Nuremburg, Germany, invented a coiled spring to take the place of the weights to drive the gears of a timepiece. Henlein's coil spring was fundamentally the same as the main spring in our watches of to-day. There was no beauty in these watches of Henlein. They were in size and shape something like a hen's egg and were made of iron and brass. Incorporated in them, very crudely, were some of the features still used in the modern watch. Many of you remember what a terribly crude affair the automobile of thirty years ago was. It was revolutionary as a transportation unit. Similarly Peter Henlein's watches, driven by a main spring, were revolutionary as timekeepers, even though they kept poorer time than the clocks then available.

The clockmakers, however, took to Henlein's invention with a vengeance and made all manner of portable clocks and watches in all sorts of shapes, like apples, pears and tulips. Many were equipped with striking mechanisms and alarms, and it is said that in Queen Elizabeth's reign when watches came into general use in society, the ladies of her court had watches made to match their various costumes, wearing them on ribbons around their necks. As early as 1550, Charles V of Austria had a watch made which was set in a ring, and there were numerous dudes around 1600 who carried walking sticks with miniature watches set in their handles.

One hundred and seventy-five years after Henlein invented the main spring Thomas Tompion, an English watchmaker, perfected the hairspring, which is still a very important part of the modern watch. This addition improved the accuracy of the watch so materially that within a year English watches were on the market with minute hands. Thirty years later a Swiss watchmaker, named Facio, patented the use of jewels for bearings in watches, and, as you know, to-day jewels in watches, when properly placed, insure accuracy in timekeeping. From this time until the next great improvement in watches there was another wave of devising unusual timepieces and those for special purposes. There were calendar and stop watches made, and one ingenious watchmaker in England devised a watch which made a round of the dial every minute and was particularly for the use of clergymen or of organizations having speakers at their meetings. He made the suggestion in his advertisement that the rules of a club should be changed to allow a man one round of the watch only, and that if he exhausted that round it should be lawful for any one of the company to call him to order. He suggested, however, two exceptions to the rule: one, that if the speaker were more than sixty years old he might have as many rounds as he pleased without giving offense, and, two, that the rule was not to extend to the fair sex. That watchmaker certainly did know the ladies.

In 1714 George Graham, another English watchmaker and an apprentice of Tompion, invented the compensated balance wheel, which greatly improved the accuracy of the watch and which is still an essential part to-day. Ninety years after Tompion's perfection of the hairspring, Mudge, a third English watchmaker, invented the lever escapement which, greatly improved, of course,

is to-day the escapement of the majority of watches. Thus by 1800 all the essential parts of the watch of the present day had been devised and applied. Additional refinements have, of course, been made since, such as the stem wind but key set invented by Charles Oudin, of Paris, in 1806, and the combined stem wind and stem set feature introduced by Adrian Phillippe, of France, in 1843. Further than that, the watch improvements of to-day are primarily the result of our increased knowledge of the property of metals combined with our own American contribution of inaugurating and perfecting a factory system of watchmaking with the design and perfection of machines for cutting gears and screws and making other parts more perfectly and uniformly than could be done by hand.

Charles Dickens once wrote to his clockmaker as follows:

Since my hall clock was sent to your establishment to be cleaned it has gone (as indeed it always had) perfectly well but has struck the hours with great reluctance, and after enduring internal agonies of a most distressing nature it has now ceased striking altogether. Though a happy release for the clock, this is not convenient for the household. If you can, send down any confidential person with whom the clock can confer. I think it may have something on its works that it would be glad to make a clean breast of.

We still need specialists for our timepieces, for we are harboring a highly pedigreed object which has a mixture of the finest English, French, German, Swiss and American genius coursing through its springs and gears. If it does show occasional fits of temperament, just excuse them, for they may have been brought on by a sudden feeling of pride in its 425-year-old family tree, or by the fact that two of its foster parents, Tompion and Graham, lie in Westminster Abbey.

RESEARCH AND INDUSTRY

RESEARCH IN FOREST TAXATION[1]

By Professor FRED ROGERS FAIRCHILD

YALE UNIVERSITY

I. Scientific Research in Industry

I am informed that it was not until after the year 1870 that any American iron manufacturer considered it worth while to employ a chemist to analyze the ore and other materials that entered into the making of pig iron. It was assumed that the blast furnace manager could tell by instinct the condition of his furnaces and the nature of the materials he used. As a consequence inferior ores were often sold at better prices than ores of higher iron content, simply because the better ores did not fit so well into the formula which some foreman, accustomed to the lower grades, had evolved. Mr. Carnegie was one of the first to enlist the services of a chemist, and he soon found that it was possible to purchase at a low price ores which on analysis proved to be of the very highest iron content. For years thereafter some of his competitors continued to assert that a chemist was a luxury they could not afford.

The former generation of American captains of industry would certainly open their eyes in amazement if they could be privileged to meet with us to-day and glance over the program of this section of the American Association for the Advancement of Science. Indeed I think that to the average well-informed American citizen this program must appear as somewhat of a revelation. Research to-day does not mean what it did a generation ago. It has pushed open the doors of the academic laboratory and the scholar's library and spread forth into all the highways and byways of industry and business. The conflict between "theory" and "practice" is becoming a thing of the past. It takes a good deal of hardihood to-day for the practical man to sneer at theory and assert that science has nothing to teach him. And the scientist, on the other hand, is learning that his science is not a mere intellectual exercise, but, on the contrary, is full of power to work wonders in the field of practical industry. Industry is showing its vitality and far-sightedness in thus calling science to its aid, and science is endowed with an increased dignity by this demonstration of its power to serve the material progress of mankind.

I regard it a privilege therefore to be permitted to preside over this meeting of those who by their presence and participation are giving evidence of interest in the progress and achievements of research in these numerous lines of science as applied to industry. Our meeting brings together a notable company of scientists, and I have full confidence that they have for us a message of interest and inspiration.

II. The Problem of Forestry

(1) *Forest depletion and the importance of forest products.* My own humble contribution has to do with a special field in which the need of economic research, while long existent, is just begin-

[1] Address of the vice-president of Section K—American Association for the Advancement of Science—at the annual meeting of the association at Kansas City, December 29, 1925.

ning to be adequately appreciated. Of the original area of virgin forests in the United States, estimated at over eight hundred million acres, three fifths has disappeared, and from the remaining forests are to-day being taken lumber and other wood products equal to four times the annual growth.

It needs no words of mine to impress upon you the importance of wood products in the lives of all of us; the fact is obvious. Failure of our sources of forest products would be a calamity whose magnitude can scarcely be visualized, and the increasing scarcity and mounting prices of forest products already mean a steadily increasing burden upon the cost of living. Our national sources of future supply of forest products are being rapidly depleted. Moreover, the great areas of denuded and idle forest lands which are being added each year to the waste lands of the country mean not only a depletion of our national heritage, but also a disturbance to the natural equilibrium which threatens serious results in interference with water storage, irregularity in the flow of streams, and erosion of the soil.

This in brief is the national problem of the forests. It may seem a far cry from this to the subject of research in taxation. That the connection is not so remote is one of the propositions which it is my task to demonstrate to you today.

(2) *Necessity of maintaining the forests.* To meet the problem of the disappearing forests it is necessary that measures be taken to preserve and restore and perpetuate the forests. Existing forests should in general be maintained by proper methods of cultivation which shall prevent denuding and provide for reproduction, either naturally or by planting. Existing waste lands, not suitable for agriculture or other nonforest uses, should be restored to forest-growing.

(3) *Reliance upon private forests.* The program must include both government and private action. For years the forest reserve policy of the United States government has been extending the area of national forests, which are of course being scientifically managed and perpetuated and improved. Several of the states also are carrying out similar programs. But with all this activity on the part of the government and with such future extension of public forests as may reasonably be anticipated, the problem must include the privately owned forests, which are estimated still to embrace about four fifths of all the forest lands of the country. It must be assumed that the major part of the country's forest area will long continue to be privately owned. The nation must lean heavily upon these private forests.

Private forestry will be guided by the economic motives which control in business generally. Owners of forest lands, no matter how altruistic they may perchance be by nature, can not be expected to handle their properties in the manner required of the public interest unless the business is profitable. Whether forestry can be made a profitable business undertaking is a question upon which opinion has differed in the past. I am not a forester or an expert in logging or lumbering, and I can not speak with authority here. However, on the authority of those best able to speak, I gather the very distinct impression that we have just about reached the point in depletion of our natural forest resources, in demand for forest products, and in rising prices of such products, where there will be sufficient and increasing motive for farsighted business men and investors to engage in the business of forest-growing provided no artificial obstacle is put in their way. And this brings me to taxation.

III. The Problem of Forest Taxation

(1) *The power of taxation.* As was said by a famous American jurist in the early days, "the power to tax is the

power to destroy." Taxation has been employed on more than one occasion with the avowed intention of destruction. Witness the present tax of 10 per cent. upon the notes of state banks, and the recent attempt—unsuccessful though it was—of Congress to debar the products of child labor from interstate commerce. But far more serious in its actual results than such cases of intentional destruction is the unintended burden of taxes imposed in ignorance of economic principles. Taxation is one of the most powerful and far-reaching of the attributes of sovereignty, its indirect consequences ramifying out into fields wholly unforeseen by the lawmakers. Though imposed quite without ulterior motives, taxation has the power to impoverish certain persons and enrich others, to divert the course of industry and trade, to influence the movement and location of population, to foster certain industries and kill others. This powerful and clumsy agent when turned loose among the delicate relationships of economic life may run amuck with results not dissimilar to those produced by the fabled bull in the china shop.

(2) *Peculiarity of forestry.* The business of forest-growing differs in one important respect from most other industrial enterprises, and it is this difference which makes forestry peculiarly sensitive to taxation and makes forest taxation a special problem. In business generally income and costs run along more or less continuously and, while material departures from the average rate of income are common enough, the entire cycle of such variations is generally completed within a year at most. In forestry, on the other hand, the rotation period is generally a very long one. A forest planted to-day or prepared to-day for natural reproduction will produce no major income for many years, twenty, forty, sixty or more, although costs may be going on more or less regularly throughout the whole period. I recognize, of course, that there is no hard-and-fast line distinguishing forestry from other businesses on the basis of this criterion. There are other types of business venture whose returns may be long deferred. And there are forests, though very few in America, which are managed, as the foresters say, for a "sustained annual yield." But on the whole this is a real distinction which will generally be found to put forestry in a class by itself.

There are in America to-day two chief types of taxation; namely, the income tax and the property tax. With the former when levied at a flat rate, the business of forestry can have no quarrel. If taxes are paid only as income is received and in proportion to the amount of the income, its long rotation period does not put forestry to any disadvantage so far as taxation is concerned. The situation is different when the income tax is progressive. Then the forest owner is in danger of a disproportional burden because of the long rotation period or the irregular yield of forestry. In the years when he receives his major income, he will be taxed in the high rate brackets, for which he receives no compensation in the years when he has little or no income. The advantages of the personal exemption and the deductions for dependents accrue to him, not every year, but only in the years when he receives an income. For example, under the United States income tax, a regular income of $5,000 a year pays no surtax and only a low rate normal tax, while the greater part of it may be tax-free on account of personal exemption and deductions for dependents. Fifty times this (that is, $250,000) received every fifty years is mostly subject to the highest normal rate and is also burdened by the surtax at rates rising to 38[1] per cent.,

[1] Since this address was delivered the Revenue Act of 1926 has reduced the income tax rates, so that the rate upon that part of a net income in excess of $100,000 is now 20 per cent.

while the personal exemptions and deductions are an insignificant trifle. Forestry is thus likely to suffer unjust treatment under a progressive income tax. There may also be discrimination against forestry in connection with the deductions for losses, etc.

(3) *The property tax as it affects forestry*. The property tax is also likely to work injustice to forestry, and since it is the form of taxation which bears most heavily upon the forests, we may profitably devote the rest of our attention to it. The theoretical basis of the general tax is that each subject shall be called upon to pay annually a tax whose amount is in direct proportion to the value of his property of all sorts except those classes of property which are specifically exempted by law. Now since the value of capital is theoretically the present worth of all its expected future net income, a tax on capital value—which is what the property tax is—is theoretically the equivalent of an income tax at a rate determined by dividing the property tax rate by the rate of interest. For example, if the rate of interest is 5 per cent., a future income of $500 a year forever will be worth today $10,000. An annual property tax at the rate of 1 per cent. would produce the same result as a 20 per cent. annual income tax; each tax would take $100 a year. The present value of all the future income of this capital is $10,000; the present value of all the future taxes is $2,000, or 20 per cent. of the capital.

But this correspondence between the annual property tax and the income tax holds good only on the assumption that the income appears annually at a uniform rate. Consider the case of a capital instrument which will yield no net income for a period of fourteen years, after which it will yield a perpetual annual income of $1,000. The present worth of such an income, discounted at 5 per cent., is $10,000, the same as the value of the annual income of $500 beginning now. An income tax at the rate of 20 per cent. on this income would exact nothing for the first fourteen years, after which it would take $200 a year. The present worth of these future tax payments is $2,000, or 20 per cent. of the value of the capital, exactly as in the case of the annual income of $500 beginning at once.

But now let us see how the annual property tax affects this second type of capital. The present worth of the capital is $10,000. The property tax at 1 per cent. will be $100 the first year. The second year, however, the capital value will have increased to $10,500, since the date at which the income will begin is one year closer. The property tax this year will be $105. Each year thereafter the value of the capital will increase and the property tax will increase until in the fourteenth year the capital is worth $20,000 and the annual property tax amounts to $200 and will be $200 each year thereafter. Now the present worth of this series of annual property tax payments is not $2,000 or 20 per cent. of the present value of the capital. On the contrary, it is $3,428, or 34 per cent. of the present value of the capital.

In this wise does the annual property tax discriminate against any form of capital whose income is long deferred. The annual recurrence of the ordinary business income is so much regarded as a matter of course that people have failed utterly to appreciate the profound significance of the annual character of the property tax. If the property tax were so devised that it fell due only when income was obtained and in proportion to the income received, its correspondence to the income tax would be universal. As it is, the property tax imposes a discriminatory burden upon all property whose income is long deferred as compared with property yielding a comparatively regular annual income. Of course the ordinary forestry

enterprise is in the class of capital thus discriminated against.

My analysis thus far has gone on the assumption of a theoretically perfect administration of the property tax. If the property tax is not administered in accordance with its theoretical intent, the result will of course be either more or less unfavorable to forestry according to the character of the mal-administration. Now the American general property tax, in its practical operation, is notoriously inefficient, its most significant aspects being deficient assessment —usually gross undervaluation—and high tax rates. The result of undervaluation has generally been to make the burden upon forest lands less excessive than would have resulted from strict application of the law. Indeed so generally has undervaluation—particularly of timber and timber lands—prevailed in the past, that it is doubtful if the actual burden of the property tax upon the forests has often been excessive. We must look farther for the crux of the problem of forest taxation.

(4) *The heart of the problem.* The general property tax is the mainstay of state and local revenue in the United States. Each year this tax exacts from the people of the United States a toll of three and a third billion dollars or more, exceeding the amount of all the taxes now collected by the federal government and being only little short of half of the total national tax bill. In spite of its notorious deficiencies, the general property tax is likely long to remain as the principal tax to which real estate at least will be subject. Under perfect administration this tax would, as I have endeavored to show, impose a discriminatory burden upon forestry. As actually administered its burden, if not excessive, is arbitrary and uncertain, with the ever-present possibility of being grossly excessive in its impact upon forestry. No owner can tell in advance even approximately what his tax obligation will be. This is bad enough for any investment. For investment in forest-growing—for an income fifty years in the future—it is a well-nigh insuperable obstacle in the eyes of the careful investor.

IV. Solution of the Problem of Forest Taxation

(1) *Results already achieved.* In seeking to solve the problem of forest taxation, the first part of the task was to determine the theoretical bases. This result has, I believe, been fairly well accomplished—at least in tentative form —by researches already made. The following conclusions are now generally accepted: (1) Special favors to forest owners are not the solution. Such favors are unfair to other interests, uneconomical, futile to accomplish the desired result and unnecessary. (2) The revenues of the states, counties, towns, etc., must not be impaired. (3) Taxation must not be an obstacle in the way of far-sighted investment in forestry. (4) In general, these ends will be accomplished by substituting the principle of the income or yield tax for taxation based upon capital value. This general program involves a multitude of details, theoretical and practical, which I need not elaborate here.

(2) *Working out the best type of forest tax.* The taxation of forests must fit into the general tax system. It must be in harmony with forest conditions and probable future methods of forest management for the various parts of the country and the various types of forest. To accomplish this is a problem of great magnitude and infinite detail. It can be worked out only in the light of practical forest and tax conditions in the several states. We are not yet sufficiently acquainted with the facts. Here is a great field for research.

V. A Plan for Research in Forest Taxation

(1) *The Clarke-McNary Forestry Act,* passed by the last Congress, made pro-

vision, among other things intended to promote American forestry, for a nation-wide investigation of forest taxation. This legislation was the outgrowth of an elaborate investigation of reforestation conditions in all parts of the United States conducted by a special committee of the Senate in 1923–24. The investigation provided by the Clarke-McNary law will be conducted by the Forest Service under my direction.

(2) *Problems to be investigated.* The field covered by the investigation will be extensive, ranging from the constitutional, legislative and traditional basis of taxation to practical matters of assessment and collection. The study will go into the land policy of timber-land owners, the purchase and blocking up of forest land units, the relinquishment of forest land for delinquent taxes, the policy of owners regarding continuous production of timber, and efforts at reforestation by owners of cut-over lands. The bearing of taxation upon all these subjects will be sought. Finally answer will be sought to the question as to what type of taxation is best suited to encourage private forestry and how such tax method may best be fitted into the existing tax systems of the several states with the minimum of disturbance to state and local finance.

(3) *Plan of investigation.* A research staff of carefully selected foresters and economists is now being organized. It will probably first be directed to make an intensive study in some selected state or region. Thereafter, when the technique of the study has been more fully worked out, investigations will probably be conducted simultaneously in several states until all the typical forest regions of the country have been covered. European experience will also be investigated for the sake of whatever light it may be able to throw upon the American problem of forest taxation. The investigation, as now forecasted, is likely to continue over a period of three or four years.

VI. Conclusion

In this brief address I have attempted nothing more than to present an outline of the present problem of forest taxation as I see it and to indicate the general character of the research upon which I have embarked under the auspices of the United States Forest Service. Humility is becoming to him who is on the threshold of his task; nevertheless I trust you will permit me at least the expression of the hope that out of this investigation there may eventually come conclusions which will be of real aid to all those who are seeking a sound and lasting solution of the American problem of forest taxation.

THE FUTURE OF AGRICULTURAL RESEARCH

By Dr. E. D. BALL
STATE PLANT BOARD, SANFORD, FLORIDA

THE production of an abundance of food and organic raw materials (cotton, wool, fur, timber, etc.) is one of the primary requirements for the maintenance of civilization. A study of history indicates that it is also one of the primary requirements for the continued growth and prosperity of a nation.

The United States has grown from ten millions to one hundred and ten millions in population in the past century, and her growth in wealth and power has equalled or exceeded that of her population. No other nation in history has ever made such a marvelous growth from so small a beginning. It is even more wonderful when we consider that it had taken the entire two centuries preceding this to produce the ten million. The greater part of the population of that period, however, was distributed along the Atlantic coast, in regions of poor soil or inhospitable climates. The past century has witnessed the opening up of that wonderfully fertile region—the upper Mississippi Valley—the greatest food-producing area in the world. As the population increased, greater and greater tracts of this prairie land were placed under cultivation, until practically all the rich and fertile portions have been taken up. During all this period, the nation has produced food in excess. The crest of that production was reached at about the close of the nineteenth century, and since that time our population has been increasing more rapidly than food production, until, if the present rate is maintained, it will be a matter of only a few years before we become a food-importing nation. In fact we have been a food-importing nation for several years, as we import more sugar, coffee, tea, spices and tropical fruits than we export of wheat and meat.

An analysis of the situation will show that it is even more serious than appears in this brief statement. Twenty of the oldest, including many of the richest of the agricultural states, actually decreased in farm area between 1910 and 1920. Several states remained the same, while the only increases were in the cutover regions of the lake states, and of the south, and in the extreme western plains area from Texas to Montana. This latter area has, since this period, experienced a serious and prolonged drouth and a large percentage of this new land has already been abandoned, and more will be in the future.

The major areas that are possible of conversion into farm land involve large expenditures for irrigation, drainage, clearing or other form of improvements, or else involve greater hazards in drouth or frost. Many of these areas can be profitably used only when prices for agricultural products are extremely high, so it seems fairly certain that the agricultural area of this country will increase, if at all, much more slowly than the population. Therefore, if there is to be increase in food production, it must largely come from the area now under cultivation.

The science of agriculture has made remarkable progress during this century—in fact, more progress than in all the centuries preceding. One man can to-day produce six times as much food as his grandfather could, and one worker in America is producing to-day four times as much food as a similar worker

in the European countries. This remarkable achievement has been brought about by a combination of many things. The improvement in farm machinery has contributed more than any other one factor, although the improvement in farming methods and practices, the marked increase in efficiency of plants and animals, and in the methods for the control of insect pests and plant diseases have all contributed their share. This, however, has been built entirely upon an *extensive* agricultural plan in which the man has been the unit and any method by which the production *per man* could be increased has been utilized. On the other hand, production in Europe has been very largely of an *intensive* character, the *acre* being the unit, for they have already reached the situation in Europe where the acre is more important than the laborer. In this country during this past century we have had acres to burn and have burned them merrily, but that day is past and if an adequate food production is to be maintained for our rapidly increasing population, our whole program of research must be reorganized and our agricultural methods revised so as to materially *increase the production per acre* without at the same time *decreasing the production per man*. The production per acre in European countries such as England, France and Germany is fully double that of this country at the present time, but the production per individual laborer is, as previously stated, only about one fourth.

Before discussing in detail this program of research, it is well to discuss some other factors on which there has been much confusion of thought. Some writers have argued that there are other areas in the world capable of immensely increased food production. One suggestion is that the blacks could be exterminated in Africa and that country given over to a white civilization which would much more efficiently utilize the area. That suggestion might have been accepted a few centuries ago. Instead, we are now carrying to them education and sanitation and helping them to develop their own civilization. We will assist them in avoiding the plagues and famines that have held their numbers in check in former generations and the result is likely to be that their increasing population will be demanding more food rather than producing an excess for the use of other nations.

Another suggestion constantly recurring is that there are great possibilities of development of excess food production in tropical regions. Gill Fillan, however, has shown that the trend of civilization for the entire fifty-four centuries of the world's history has been steadily away from the tropics to the temperate regions and this trend seems to be even stronger at this time than in the past. It seems to the writer that utilization of the tropics is much more likely to continue along the line of production of beverages, tropical fruits, spices, rubber and other semi-luxuries as in the past, rather than to become an area from which we may expect any amount of increase in substantial food items. These areas will undoubtedly be increasingly used for recreational and outing purposes, as sanitary and health conditions improve. We must remember, however, that wherever civilization has removed the land covering of timber, grass or shrub, it increases the severity of both drouth and floods and, that especially in tropical regions with excessive rainfall, this results in severe gullying and washing which depletes the fertility of the soils and if carried far enough eventually ruins large areas. Civilization also takes a large toll from the cultivated areas. Cities expand and take up the richest and most fertile river valleys. Increased populations require more roads, boulevards, parks and pleasure grounds, country estates and golf courses, all of which

take from the productive area. City taxes have ruined many a farmer while actually enhancing the value of his land.

There is another factor that appears to be little understood, and that is that neither the state nor the nation appropriates money for research to assist the farmer alone, any more than they appropriate money to assist the blacksmith, the carpenter, the lawyer or the clerk as such. Agricultural research that assists the farmer to produce food and raw materials beyond his own needs adds to the abundance from which the rest of the world gets its supply. It is only from the excess that the rest of the community can be supplied. In fact, increasing the production for the farmer has oftentimes resulted in immediate financial injury, through low prices for his product, but it has always worked to the benefit of the consumer in lowering his food costs.

There is another factor that needs to be emphasized and that is that any one who contributes a new and valuable idea or method in industry is allowed to patent his process and obtain his reward through the control of its production. There can be no such arrangement in agriculture. If a man produces a better wheat he must first have it tested by many individuals in many localities before it has been determined that it is valuable, and by that time each individual becomes his competitor in supplying this new product. If he is able to sell a few bushels in the beginning at a higher price, practically every bushel will be used to develop competition. In the same way if he has improved an animal the process will be repeated. In either case he has made a valuable contribution to world progress comparable to that of the discoverer of a new process in industry, but he must depend upon the state or the nation for his reward. With this situation understood it will be clearly recognized that the appropriation of money for agricultural research is appropriation to the development of a fundamental industry in which national prosperity is involved and that its immediate and direct benefits accrue to the consumer to as great if not greater extent than to the producer.

It must also be recognized that the agricultural problem becomes increasingly complex with the increase in population and especially with the increase in rapidity and ease in transportation. A generation ago, when each farmer was more or less isolated and produced a large variety of crops, many of the problems with reference to the control of insect and plant diseases were unimportant, but to-day with specialized crops concentrated in given areas, every known insect pest and plant disease is likely to be introduced and, finding an abundance of food, to multiply and become increasingly injurious. The increase in rapidity of transportation has of recent years trebled the difficulties of the producer. A large number of the most serious insect pests and plant diseases and many of the most troublesome weeds are of recent introduction. The boll weevil and the pink boll worm of the cotton are the two most serious handicaps to its production. The corn borer is moving from the eastward towards the corn belt. The alfalfa weevil introduced into Utah has recently crossed the mountains in its eastward march. The chestnut blight has eliminated the chestnut. The white pine blister rust is menacing our second growth forests. The Japanese beetle and the Oriental Fruit Moth are beginning a destructive march on our fruit industry. With these and many other additions to the problem of production, as well as those inherent in concentration of area, the farmer of the future must have increasing help to even maintain the production of the past. If, however, he is called upon to greatly increase the production per acre there must be still fur-

ther additions to the research facilities provided for the solution of his problem.

We must remember in this connection that agriculture is not a science, but that agricultural science so called is the application of the principles of the various sciences to the agricultural problem. In the same way agricultural research is divided into the primary fields of scientific research, the only difference being that in this case the research is being applied to the solution of problems that will contribute to the development of food and raw materials.

Much of the remarkable progress in agriculture during the last three decades was due to the fact that there was a very large body of scientific knowledge waiting to be applied to the agricultural field. At first sight, it would seem that progress in the future would probably be slower because of the fact that the easier applications had already been made; but instead of that, it seems certain that progress in the future may be expected to be more rapid than it has been in the past.

A large number of far-reaching scientific discoveries have been made in the past few years. They have already opened up many new possibilities and opportunities for application to the agricultural field. What future discoveries will contribute can only be conjectured and need not be considered at this time as there is plenty of material at hand for outstanding contribution. The discovery of the colloids opens a fruitful field for further research in soil physics and chemistry. It has already contributed to the science of road building and has many applications in the agricultural field. The discovery of vitamines, of the influence of the ultra-violet light, as well as the effect of the length of day have opened a wonderful field of opportunity for research in plant and animal physiology, nutrition and development. The development of new insecticides and fungicides, together with new discoveries in the biological field, have given increased opportunity for insect pest and plant disease control. Many new discoveries in the field of genetics and the organization of our previous knowledge have brought that science to the point where it is apparently able to contribute materially to practical plant and animal breeding. The thorough and fundamental researches that have recently been made in the field of economic science is preparing the ground upon which a rational and effective system of marketing and distribution of the agricultural products may be built. With this array of new information available for application in the agricultural field, we may with confidence lay out a program that bids fair to far surpass the achievements of the past.

While steady and continuous advance will no doubt be made in all fields of research there are certain fields in which the opportunities will undoubtedly warrant an increased emphasis at the present time. The economic features have lagged far behind most of the other sciences. The increasing appropriation to be devoted to this field under the new Federal Fund, together with the rapidly accumulating body of facts from which deductions may be made, warrants the stressing of the opportunity in this line. The greatest handicap to the development is undoubtedly the lack of a sufficient body of adequately trained men to gather this information and interpret the results.

The whole breeding problem, both plant and animal, is in a position to warrant a very decided increase in its research activity. Up to the present we have worked almost entirely with the plants and animals bequeathed us by past generations. There should be increased effort in plant and animal introduction for the purpose of testing their possibilities of domestication, but more

especially for their possibilities of contributions through hybridization in the development of still more economic and productive plants and animals. Breeding for resistance has only just been initiated. Many of these wild strains may contribute possibilities of resistance to different diseases or pests, as the case may be, that may make them extremely valuable. The plants and animals of the future must be more highly resistant to many factors and especially to those for which no other method of protection has as yet been developed. Cabbage resistant to yellows, one of the most destructive of cabbage diseases, is already an established fact. Corn resistant to smut is now growing in experimental plots. Wheats resistant to different strains of rust have already supplanted less resistant varieties. There is a tremendous field for accomplishment in all these lines.

In the field of farm machinery, buildings, highways and in the use of electricity there is an excellent opportunity for research that is just beginning to be appreciated. We are expending nearly a billion dollars annually building highways. The research necessary to determine the methods and materials to employ in the construction of a permanent and satisfactory highway were not even started when this enormous building plan was inaugurated. The best we can hope is that we will know how to build a road by the time that we have the most of them built. This might well be cited by the pessimists as one of the outstanding examples of the inefficiency of democracy.

The losses from insect pests and plant and animal diseases annually run into hundreds of millions of dollars. The additional sum annually expended in holding their destruction in check is a heavy drain on the profits of the agricultural enterprise. There will undoubtedly be a tremendous advance in the efficiency and economy of the control methods, but equally important, if not more valuable in the long run, will be the possibility through added knowledge of biology and the use of more efficient control methods of entirely eliminating certain of the outstanding pests and diseases through eradication methods.

Few realize the contribution to the general welfare of the eradication programs already carried out or under way. These, combined with an adequate method of preventing introduction of further pests and diseases, have been large factors in enabling the farmers of America to compete successfully with those of other nations.

This nation has been a very large exporter of meat and meat products largely because it has been the leading country in the world in protecting its live stock from destructive diseases. The eradication from this country of an introduced outbreak of haemorragic septicemia marks the beginning of this work and the founding of our Federal Bureau of Animal Industry. The quarantining of the tick-infested areas and the eradication of the Texas fever of cattle from two thirds of the original infested area in the United States has been a wonderful achievement, and apparently the day of the elimination of this disease is not far distant. The eradication of tuberculosis from the herds of this country started but a few years ago, but is already under headway in every state of the Union, with one possible exception. The eradication of tuberculosis in cattle has resulted in the reduction of this disease in hogs, in chickens and in human beings. It was not started as an eradication program, but the possibility of carrying control to the point of eradication developed and the stock men have been so thoroughly impressed with its benefits that they are constantly demanding larger appropriations that the work may proceed more rapidly.

The entire eradication of citrus canker from the commercial citrus area of Florida at a time when it was threatening to entirely eliminate the industry from that region is one of the most striking and encouraging examples of plant disease eradication work ever accomplished. The successes in these fields warrant the conclusion that with the development of more biological knowledge and better methods and processes a very large number of new eradication programs may be undertaken in the near future.

The American Foul Brood of the honey bee is the most destructive handicap to that industry in this country. Recent discoveries in its biology and in methods of distribution have shown that it is entirely possible to eliminate it from a region. The ox-warble, the grub in the backs of cattle which bore holes through the hide, ruining it for leather and causing serious losses to growing cattle, is another pest that can be easily eradicated. New and more efficient methods of destroying these grubs have recently been discovered and are being perfected. With only a little more research work, methods will undoubtedly be perfected which will make it possible to put on a campaign and entirely eliminate this serious overhead on the live stock industry. The cotton boll weevil feeds only on a single plant in our territory and removal of that plant for a period of two or more years could easily be carried out. This country will undoubtedly be divided into zones, and eradication of this pest undertaken sometime in the future. The codling moth is entirely dependent on the fruit of the apple and the pear for its existence. A little further development of methods will make it possible to take advantage of years of serious frost damage to eliminate this pest from commercial apple growing regions. The loss from these two insects is more than the entire profit to the producers at the present time. There are a large number of other insect pests, a certain number of plant diseases, a number of animal diseases and no doubt a considerable number of seriously injurious weeds that might be eradicated when the research programs to this end have been perfected.

From the foregoing brief summary of opportunities there is evidence that agricultural research has an almost unlimited field and that its contribution will be limited only by the funds available for its prosecution. As has been pointed out, this must be subsidized by the state, the nation or by the industry affected. In the case of agricultural research, owing to the fact that the increase of agricultural production is for the benefit of the entire nation, it should be nationally supported. Money appropriated to research should be considered as one of the best investments possible to make from the standpoint of insuring national growth and prosperity. A study of the history of nations will show that their growth in the past century has been almost directly proportional to the amount of money that has been expended for education and research. For education must be recognized as a preliminary requisite to research from two standpoints—first, the universal education which raises the intelligence of the masses, thereby enabling them to grasp and use improved methods, and secondly the advanced education which is absolutely essential in the training of the research men. Much time could be properly spent in discussing this feature. If one will compare the development of Japan with that of China, of Germany with that of Spain, or the development of this country with that of her sister republics to the south, he will recognize that the money expended by these governments in education and the application of research to agriculture and industry has been most wisely expended from the standpoint of actual financial returns in income to the nations, to say

nothing of the prosperity and intelligence of the peoples.

It must also be recognized, in this connection, that leadership is the prime requisite to success in fundamental research. A man of vision, of inquiring mind, imbued with the real spirit of the scientist, which is public service—the service of mankind—is the only capable leader in an investigational field. Equipment and environment are more or less necessary, but these can be purchased—the man must be found.

Great contributions to world progress in the generations past have been made by relatively few men and this will always be true. There are literally thousands who can effectively work out details, expand ideas and trace relationships, where there is *one* individual who is capable of freeing himself from the shackles of the accepted, who is willing to leave the beaten path and actually explore, who holds all information as relative and subject to investigation, who is capable of creative work, who can analyze and evaluate factors and interpret results. An architect with a master mind visions the great cathedral; hundreds of workmen, stonecutters, carpenters and masons work out the details and bring the structure to completion. Not one of these workmen, however, could have conceived the structure. Without the master mind it would never have existed.

It should also be borne in mind that for the type of research that has been outlined, there is need of thorough training and that we must see to it that our educational institutions offer opportunity for this type of training to all who seek it. There has been in the recent past too much of a tendency in many of our institutions to stress the practical side of their training and to neglect the broad fundamentals. We must remember that in agriculture, especially, the farmer is not an artisan to be minutely trained in the details of one special craft. He is rather the manager of a broad and varied enterprise which requires continued adjustment to meet varying conditions. If he is to be highly successful, he must be broadly trained and depend very largely for his success on his ability to reason rather than upon his obedience to precept.

In this connection it is well to consider another biological law—that there is no standing still in nature—that all living things are either growing and developing, or decaying and approaching dissolution. This is as true of the social organization as it is of the individual. A nation must either continue to grow and develop or the germs of decay will be gradually infiltered into its body politic and its final end will be only a question of decades or at the most a few centuries.

The time has arrived when America, if she is to hold her place among the forward-looking nations, must recognize her dependence upon research and proceed at once to organize her scientific forces to attack the problem at hand and especially to encourage scientific investigation and development in agriculture and industrial lines tending towards national development. This nation is to-day coming to be recognized as a leader among the nations of the world. It is a position which carries great opportunity and still greater responsibility. The foresight of our forefathers in establishing universal education and a wise policy of national development have given us this opportunity. That educational foundation was laid at a time when it was a serious financial burden on the growing colonies. The wisdom of that policy has, however, been abundantly demonstrated. Will the leaders of our nation at this time recognize that this nation is at the crossroads—that the abundant supply of food and raw materials which has been the basis of our prosperity is threatened and that it will only be possible to guarantee its perpetuity by a marked increase in the support of the research organizations under which it has been developed?

EVALUATING RESEARCH IDEAS

By Dr. F. O. CLEMENTS

GENERAL MOTORS CORPORATION, DETROIT, MICHIGAN

JULIUS BARNES makes the statement that "during the last two decades, science and invention have aided the progress of industry as in no preceding similar period." He gives the following interesting comparisons:

1900 to 1920—

Population,	increase of	40	per	cent.
Food products	" "	58	"	"
Mine products	" "	128	"	"
Factory products	" "	95	"	"

He further states that "there is not only the normal increase of an enlarging population and the normal increase which follows a resumption of the constantly advancing standard of human possessions, which has been the feature of our national growth, but there is besides the acceleration of the standard of human possessions by the very enlargement of human earning power, which science and directing genius has made unmistakably effective."

In other words, we have greatly expanded the employment opportunities and made more secure the common standard of living, which is peculiarly American. We rely as never before on the continued service of science and invention translated into human needs through the processes of large scale industry.

Mr. C. F. Kettering, president and managing director of our organization, likes to vision this advance somewhat in this fashion:

Egypt, Rome and Greece reached the highest stage of their development when they had the largest number of slaves, which increased the productive capacity of their civilization. Our own civilization has kept growing, despite the abolition of slavery, because of the development of mechanical power. Every man, woman and child in the United States has at his command six horse-power, or the equivalent in work of one hundred and fifty slaves. We do not recognize these slaves. Some bring water into the house, others bring light, some carry messages, and all sorts of slaves are available to relieve the individual of physical labor and discomfort.

Incidentally, this multiplies our personality many fold.

It is a great heritage, indeed, to be a native child of this favored country, where equality of opportunity still exists and men rise to great heights through sheer ability. We are living in an age in which new impressions crowd upon us so rapidly that the miracle of yesterday is forgotten and displaced by the still greater achievement of to-day.

Chart down the great inventions and discoveries of the quarter century and note the part that science and engineering have played.

Aluminum—the Diesel engine—the Otto cycle, resulting in the automobile—X-rays—radium—wireless and radio—the airplane—the tungsten lamp—moving pictures, etc.—marked advance in every field of endeavor. Twenty-five years ago there were comparatively few efforts at systematized research in the entire country. Research, as we know it to-day, was an untried experiment. Developments garnered from everyday necessities and simple observations will not answer to-day. The everyday world has become quite technical and complex—so much so that we can not hope to maintain our position, without the assistance that science can render.

Research—which means "to search and examine with continued care; to seek diligently; to search again; to examine anew"—is really only organized, scientific study to insure the purposeful seeking of new knowledge. It is essential that the unknown be explored; for the acquisition, development and application of new knowledge is necessary for continuous growth. We progress through change—Research has been designated by innumerable names: "The life-blood of progress"; "the creative force of industry"; "the mother of industry"; "the future of industry"; "the welfare of the race." Pasteur says, "Science is the soul and the prosperity of nations, and the living source of all progress." If these flattering terms are deserved, it involves great responsibility on research personnel, relative to the selection of worth-while problems. The ancestor of every human action is a thought. Our only assets in research are ideas, and the thought world in which we labor is infinite.

The most difficult of all questions in a research laboratory is the selection of the task and the enlisting of the proper cooperative effort so that the whole organization may act effectively, until the problem is solved. Good judgment in selecting the problem is paramount. This task is extremely difficult, and our method of evaluating a device will be discussed at some length. A good idea must be measured by the actual personal service it can render to humanity, for the customer who utilizes the new development is the final arbiter of its fate. In the automotive industry our customers' wishes are paramount. Our entire research program is fixed by our interpretation of what the prospective customer desires. Consequently, every idea must run the gauntlet of public opinion.

The automobile has probably done more than any other single invention toward educating the American people in mechanical ways of performing everyday tasks. It is largely since the introduction of the automobile that people have been interested in household and farm machinery to a constantly growing extent. The psychology, or style factor, which perhaps may be reduced to the instinct for superiority, is one of the most important of all those connected with the automobile development. This means that the car must not only operate simply and satisfactorily, but must also appeal to the buyers' fancy from the standpoint of beauty and comfort. The effect of these factors on the car of today is greater comfort, smoothness of operation, good acceleration, simplicity of upkeep and ease of making replacement and repairs, as well as a good bit of beauty in body lines and color.

Groups of trained and well-educated men are brought together, properly housed, and furnished with adequate equipment, and are set to work on the major problems of an industry. Men of initiative are sought, and they work tirelessly in a definite place on a single problem, until success comes. An organization of trained minds is vastly superior to the old system of scattered effort, where all investigation was done by unattached individuals. That was the day of the inventor and his products were rarely useful, commercially.

The ultimate object of all research is twofold: to increase the earning capacity of the corporation or individual, and to fulfil the obligation of all really important business organizations; to contribute something constructive to society. There can be no excuse for unsound ideas. Engineering really came into being, when men substituted exact methods of measurement for guesses and opinions, and it is on the foundation of exact facts that big industry must build to survive. Engineering research applies ways, means and methods that science has developed to observe, experiment, measure and verify facts. To count is a modern practice: the ancient

method was to guess; and strange to say, when numbers are guessed, they are usually magnified.

There is still too much theorizing in business without proper accumulation of proved facts. The truly educated man refuses to be guided by prejudice. The uneducated has no other guide than prejudice, and material prosperity makes the prejudices of an uneducated man aggressively and destructively harmful to the social and economic life of which he is a part.

Research boiled down to its essence is nothing but self-education. Before we can direct our thoughts along profitable channels, we must study a problem intensively and know its fundamentals. Every bit of help available is focused on the problem at hand. The technical library presents abstracts of articles appearing in the literature, representing the best thought of the world's workers on the particular subject. There are untold millions of work hours stored up in our libraries. Sometimes it would seem that we have enough available data, and fail to utilize it to its full advantage. One of our secretaries of agriculture once said that "if we would only utilize the knowledge that we possess, we could overnight double our yield of agricultural products." So the search for things that have been done is of vital importance. The patent art must yield its contribution so as to steer the study successfully, to avoid infringements with other ideas. Research must be orderly, to be successful.

Knowing the importance of initiative and enthusiasm in research workers, we do everything in our power to further these desirable properties. Scientific research must be untrammeled and free from restraint. Each section head is allowed a certain appropriation to help him determine the value of an idea. Some prefer to make the preliminary calculations on paper; others reduce them to small wood or metal models. If the idea develops well and seems sound, a request is made for a project appropriation. Prior to a request for approval, we try to evaluate the usefulness of the idea ourselves. Somewhat after this procedure, which applies equally to pure and applied science problems—for there is only one objective: the search for truth and knowledge. The thought first; its proving and application last.

All research work with us reflects itself on the products which our corporation makes and sells. A research project, to be worthy of a place on our program, should do one or more of the following things:

(1) Reduce costs of production;
(2) Reduce operating costs to the user;
(3) Increase the utility of the product;
(4) Increase its sales appeal;
(5) Produce new business;
(6) Determine technical information contributory to some other project.

The relative value of the proposed project is based largely upon the quantitative value of the analysis itself. For instance, our rubber research applied to fan belts resulted in a long-lived product at a reduced cost, which benefited the entire industry. This project, following this economic survey, was allocated in value, somewhat on the following basis:

10 per cent. reduction in cost of production;
30 per cent. reduction in operating costs to our customers;
50 per cent. increased utility of the product;
10 per cent. technical information applicable to related rubber projects.

It actually worked out with a much larger saving in cost of production and influenced engine design in an extremely favorable way.

All our problems are submitted to this type of analysis. It helps in keeping our work extremely practical and in insuring a better utility at a lower cost. This project now analyzed and approved by the research organization goes to our

executives for final approval and the allocating of funds to carry on the work. Our executives are men of far vision and have had years of experience in the automotive industry. All our ideas after development into final form ready for production get a thorough tryout by our various subsidiaries, the General Motors Proving Grounds, or in some instances by selected customers. Customers have the peculiar habit of doing things with a new product that are beyond imagination. The new device must be sound in principle, reliable in service, reasonable in cost and fill a real need. You may say this is putting a development program on a money basis—it is and quite properly so. I would cite you to Pasteur's selection of tasks, all of which were fundamental in scope and still extremely practical; we reap the rewards of his work more and more as time goes by.

In carrying on the work, we usually try to vision the ideal so that we can establish a yardstick of performance; we then design, first for quality, and later study the simplification of the product, which introduces the economics.

Our problems are mainly electrical, chemical, physical, metallurgical and mechanical. We try to contact all plant engineers and managers during the progress of the work, to insure its filling an actual field need, and to keep the work practical. This contact, furthermore, assists materially in the early commercialization of the development. We feel it is necessary to follow this procedure, for our problems are absolutely innumerable. We have more than we can do and must by necessity choose wisely.

Pure science workers rarely know what end they will achieve. Without fundamental studies and their cumulative results, nothing can be intelligently applied. Finding the use for an accumulated fact is also research. It includes the study of the commercial requirements and the problems pertaining to practical production. Results, despite great care, are sometimes intangible, but after all the general product of research is information. Like most valuable things, information founded on facts and truth comes in small packages and usually represents a maximum amount of hard mental labor. A worth-while research program must carry a goodly percentage of pure science research, for it is the seed corn containing the program that lies just ahead, the magic power that is extending the boundaries of every field of human endeavor. It affects our mental aspect, our entire social structure and even decides the economic fate of nations.

All credit to these faithful research workers, who toil tirelessly to add to the sum total of human knowledge. The one thing that keeps us faithful to our trust is the knowledge that "truth is mighty, and bound to prevail."

MODERN CARDIOLOGY

By Dr. STEPHEN D'IRSAY
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THE science which deals with the heart and circulation in health and disease is called cardiology. Ever since the circulation of the blood was discovered by Harvey in 1628 attention was never lacking in the study of that fascinating mechanism, and this attention has increased very greatly during late years. This is not surprising: the obviously intimate connection between the functions of the heart and the maintenance of life stimulate human interest powerfully and the purely scientific aspects of the study, unfolding one by one, were able to satisfy the most searching intellects. The following lines endeavor to present the chief advances that were made in the exploration of the heart in recent years and the principal problems confronting those interested in cardiology shall be pointed out.

As in all fields of scientific progress, advance in this field too depended and depends chiefly upon advances in method: the evolution of accurate equipment and exact technique. The last decades saw the development of a refined anatomical workmanship, particularly in that branch of anatomy which surveys the microscopic structure of the organisms—histology. Since structure and form are fundamentally important attributes of organs and organisms it is only natural that we should consider first of all discoveries which have been made in the realm of structure by anatomists and histologists. Of these, the discovery of a special muscle system in the heart was possibly of the greatest moment. This system consists of an accumulation of cells near the entrance of the great veins into the right auricle of the heart, a bridge of muscular tissue connecting the auricles with the ventricles and ramifications of this bridge, spreading in fan-like fashion and enveloping the interior of these chambers. The work of men like Sir Arthur Keith in London, Professors Aschoff in Freiburg, His in Berlin and Dr. Tawara in Tokyo revealed thus the existence of a structure whose function is of great importance. It is now known that the impulse driving the heart on in its rhythmic action is formed in that very accumulation of cells, that this impulse runs through that bridge and rapidly spreads along the fan to every part of the ventricles. Even our naked eye shows us in the exposed heart how the different parts contract one after the other in precise sequence, how the blood passes through each section to be at last expelled through the large arteries. The anatomical discovery of this bridge-system furnishes an admirable background for this successive activity: it gives the clue to the coordination of the movements in the heart. In only a few more systems in the human organism is anatomy so closely interwoven with physiology, form with function as it is here—the central nervous system and the kidneys are other examples; form and function render one another mutually intelligible in a very lucid fashion.

Engelmann, the late Utrecht physiologist, advanced a workable theory concerning the fundamental properties of the heart muscle. According to this theory, the heart muscle possesses certain qualities in virtue of which it per-

forms its rhythmic contraction. These basic qualities are: the formation of an impulse resulting in a constant rate, the conduction of this impulse—the function of the muscle bridge mentioned before—into various sections of the heart; the so-called irritability—the ability of the muscle to react to the impulses thus formed and conducted—and contractility: the power to actually contract and perform work. Immediately there comes to our mind a fundamental—although purely theoretical—question: what is this mysterious impulse which causes the heart to beat in constant rhythm? The answer to this is by no means definite, but hints have been given toward the direction in which truth lies. A famous biologist of the eighteenth century, Albrecht von Haller, explained that the cause of the heart beat resides in the heart itself and not in nerves or other structures outside of it. The recent work of Professor Mansfeld, a Hungarian pharmacologist, seems to confirm the truth of this assertion. His experiments point to carbon dioxide as the constant normal stimulus of the heart, the same carbon dioxide which has been long known to govern the rhythm of respiration in man.

One of the most signal achievements of cardiac physiology and one that helped most to understand the functions of the special muscle system—to which I was referring above—in both health and disease, was the construction of the string galvanometer by Professor Einthoven, of Leiden, Holland, the Nobel Laureate of 1923. It has inaugurated electrocardiography, which is now an important and widespread method. It would not be amiss to discuss this phase briefly, in view of the clearness with which the bearings of physics upon modern methods of physiology and scientific medicine are demonstrated. Every tissue, in animals and plants, produces electricity when in motion. Chemical energy is being stored in muscle—the tissue of motion par excellence. This energy (according to the large principle of the conservation of energy) is transformed into a certain tension of the surfaces (surface-energy), this in turn into electrical, heat and mechanical energy. This phase of electrical energy appears in the form of minute electrical currents which can be led off the contracting muscle and measured. The heart muscle is no exception. It, too, produces such minute currents when in action and the direction and shape of the deflection caused by such a current will vary according to the place in the muscle system that produces it. The method of recording these so-called action currents is based upon a physical principle (Ampère's rule). Electrical currents when shunted through a conductor in a magnetic field will cause the deflection of this conductor according to the direction taken by the current in passing through it and according to the voltage of the current. Now, in the string galvanometer, this conductor is an extremely thin string suspended between two powerful electromagnets. Through this string passes the current generated by the heart and distributed along the entire surface of the body. If we connect arms and legs (representing the two poles of electricity produced) by the means of electrodes of some sort (water-baths, water-soaked wire and gauze, hypodermic needles, etc.) with the string, we lead the action current of the heart into it, provided some other electrical operations have been performed. These are of a very technical nature and I omit them here, as they are irrelevant to the visualization of the main process. The magnets are pierced by two microscopes, one of them serving the purpose of throwing the beam of an arc light on the string, the other to magnify its image and project it upon a rotating film. Photographic pictures of the moving string are thus obtained and our curves will give an accurate description of the

condition of the heart muscle in which the action current is formed. One section after another is engulfed in activity and the deflections of the string of the activity faithfully follow the sequence in these sections. It is clear therefore that every deviation in the normal sequence of contractions in the heart finds its true expression in the electrocardiographic record.

Many were the discoveries made with this apparatus, Einthoven himself, Sir Thomas Lewis, in London, and Dr. Winterberg, of Vienna, setting the pace in this series of discoveries. Great hopes are vested in the possibilities of the instrument. Among other things we may expect a clear elucidation of the actual mechanism of both the beginning and the end of human life. Concerning the first I have in mind possible embryological experiments along the lines developed by Wilhelm Roux to establish the actual time and circumstances when and how the formation and conduction of impulses in the heart commences. Concerning the second, let us listen to an old statement. Twenty-five years ago Professor Nothnagel, the Viennese clinician, stated in a famous lecture that the immediate cause of death is always found in the heart. The statement is true with the modification that the failure of respiration should be included among the immediate causes of death. However, it may well be asked what the exact mechanism is that stops the heart. The electrocardiograph begins to answer this question. In numerous cases—both in human beings and in experimental animals—a peculiar incoordinated movement of the ventricles has been observed. The fibers contract individually, and it is obvious that this prevents orderly contraction and expulsion of blood. Accordingly, the condition—known as ventricular fibrillation—is incompatible with life. Professor Hering, of Cologne, who, together with Sir Thomas Lewis, did much to throw light upon this fibrillation, suggests that it is the commonest mechanism of death.

But the main practical importance of the electrocardiograph lies in another field. The outstanding service rendered by it was that it made us understand clearly the irregularities of the heart. A thorough knowledge of the mechanism of these disorders was the first step toward their evaluation and placing into a clinical scheme according to their significance for diagnosis and outlook. This process of evaluation is not at an end yet, although it is very well under way, *e. g.,* we still do not know the meaning of the so-called extrasystoles: occasional beats occurring outside of the regular rhythm. This too is bound to come. To be sure, this work did not wait for the electrocardiograph. The late Sir James Mackenzie, of London and St. Andrews, and the Dutch Professor Wenckebach, in Vienna, did a great deal to interpret these mechanisms, some of which are highly intricate and require sharp and concentrated thought. Their work was masterful and deserves the more credit, as it was done solely by the aid of simple graphic methods invented long ago by the father of graphic work in physiology, Marey, in Paris. Such graphic methods are the recording of the arterial pulse and the pulse of the great veins on the neck. It is admirable to what extent complicated events were disentangled by simply analyzing the arterial and venous pulse. However, these efforts needed the exact and final confirmation of the electrocardiograph. This instrument enables us to discriminate very nicely between the various irregularities and standardize them, so to speak, whereas a few decades ago they were all thrown together. While formerly all of them were looked upon as serious disturbances, now we know that some might be serious, while others do not threaten life. A reorganization of treatment follows in the wake of these findings. Electrocardiography made

great strides in America: the technical work done here excels the accomplishments of most other countries. Thorough physical and mathematical analysis had, of course, to precede any attempt to construct and operate string galvanometers and in this direction—besides Einthoven—the lead was taken by Professor Williams, of Columbia, who devised the most perfect electrocardiograph in existence. String galvanometers—which are manufactured in the United States, in England, France and Germany—now form a standard and indispensable equipment of large hospitals and physiological laboratories.

While electrocardiography is engaged in discovering the formation and conduction of the motor impulse but does not study the process and results of the actual contraction of the heart as a whole, another branch of cardiology—cardiodynamics—is interested in the latter phenomena. It studies and tries to establish the rules under which the heart as a whole maintains its pumping activity. The aim of all natural science is to achieve a quantitative basis for all recorded events, and this aim has been successfully approached in this difficult territory. The best recent work in this field has been done by the late Professor Tigerstedt, of Helsingfors, in Finland, Drs. Frank, in Munich, Starling, in London, and Wiggers, in Cleveland. The problems they investigate are the duration of the whole or of certain parts of the cardiac cycle, pressures and changes of volume in the chambers of the heart and how the output varies under all kinds of conditions, together with the variations of mechanical energy that lead to such changes of output: to give an idea as to the nature of this work. It was possible, in the end, to develop a mathematical formula which expresses the work done by the heart during each one of its cycles in an adequate and concise fashion. This remarkable achievement, which can not very easily be multiplied in other departments of physiology, is due to precise technique. Methods of approach to dynamic problems are many and interesting, and they increase in number since Langendorff, of Rostock, and Starling—to mention but a few—taught physiologists how to keep an isolated mammalian heart alive. Manometric records have been obtained from all chambers of the heart as well as from the large vessels; and dynamic problems have been extended from the heart alone to the circulation as a unit. Determinations of the blood flow in limbs and surviving organs or in the whole body; the effect of nervous influences and internal secretions upon phases of the circulation and various other sets of problems may be classed within cardiodynamics with enlarged scope. Interest in certain organs has been revived in this connection. The capillaries, although forming the bulk of blood-conveying tubes in the organism, their cumulated cross-sections being very much larger than that of the large arteries—have long been neglected. Recently Professor Krogh, of Copenhagen, thoroughly investigated the working conditions of these minute but extremely important tubes, discovering their independence and self-regulation according to the needs of the special organ which they feed. It is ultimately in the capillaries that the exchange between tissues and blood takes place, and the supply of tissues with oxygen and other substances of nutrition depends in no small degree on the way they are working and the conditions they are in.

I mentioned the perfused heart. The problems presented by such hearts—cold-blooded or mammalian—are innumerable. The human heart has been kept alive by the means of artificial perfusion fluids, by Kuliabko, of St. Petersburg. The chemical and physical conditions necessary to the normal rhythm, conduction of impulse and dynamic work of the mammalian heart have been investigated

one by one with success. The latest contribution to our knowledge concerning these conditions comes from Professor Zwaardemaker, of Utrecht, who demonstrated that radioactive substances are interchangeable in the nutritive perfusing fluid. This elegant work adds greatly to the elucidation of the broad and fascinating problems of relations between chemical constitution and physiological function. It is needless to add that information of this kind is the foundation of all scientific pharmacology and clinical application of drugs.

The evaluation of the various cardiac drugs has also been markedly advanced with the advent of the perfusion methods. Of these drugs digitalis stands in the center of interest; its possibilities are by no means exhausted, although about a hundred and fifty years have passed since its usefulness was discovered by the English physician, Withering. The action of digitalis and the other so-called digitalis bodies (such as strophanthus, etc.) upon various circulatory functions have been investigated over and over. These substances exert influence upon the width and adaptability of the walls of vessels, upon the nervous centers regulating this and the rate of the heart. upon the amplitude of contraction and expansion, upon the output of blood: as we see, an influence which is widespread and constant. An immense amount of experimental work has been done concerning this famous drug—one of the six really great drugs in the estimation of Sir William Osler—and observations on man have been piled up. Nevertheless there is no standardized method of growing the plant from which it is derived (*Digitalis purpurea,* or the recently discovered variety *Digitalis lutea*) under uniform conditions or of administering it under strictly uniform, scientific rules. In this direction there have been many and valuable efforts on the part of investigators like Drs. Cushny, of Edinburgh, Eggleston, of New York, and Edens, of Munich. Still, the problems to grow plants containing the drug in known amounts and of standard quality, to extract the chemically and physiologically active alkaloid from the leaves and to isolate it and to establish definite rules in treatment, are still unsolved. As digitalis is the most powerful drug in the therapy of heart disease, interest in it will never be lacking and these problems are certain to be solved in the near future.

There is another point to be noted in connection with therapeutic researches in this case and that is that digitalis acts only on hearts that fail to do their normal work (which are, in other words, physiologically insufficient) and those that are hypertrophied, increased in size, an observation which directs a rational approach in the experiment. Another fact came to the surface, and that is that the action of this substance—and also of many others—depends to a great extent on the chemical composition of the blood, most particularly on its chemical reaction (to use modern scientific parlance: its hydrogen-ion concentration). It was even found that the bottles containing digitalis extracts influence the efficacy of these extracts on account of the minute amounts of alkali given off from the glass.

The pathological anatomy of the heart, too, has made decided progress. In this field research centered around such questions as: what are the morphologically recognizable diseases of the special muscle system and what is the anatomical picture that corresponds to the condition known as heart failure. This latter problem is closely interwoven with inquiry into the true anatomical features of hypertrophy and dilatation of the heart. In these investigations the leaders are Professor Aschoff, of Freiburg, and the late Professor Mönckeberg, of Strasbourg. It comes to be recognized that the hypertrophy of the heart does not mean merely a quantitative increase

in the number of fibers constituting muscular tissue, nor is it a simple increase in their size: if such were the case, hypertrophy of the heart would be just as physiological as the hypertrophy of any hard-working muscle. We would not understand why such a quantitatively strong muscle would give way all of a sudden. But hypertrophy of the heart muscle is in a sense always pathological: the intricate metabolism of the fibers is injured and anatomical proof is forthcoming of this injury. Anatomical research also pointed out another fact of great importance, to wit, that an infection, if it damages the heart at all, damages all its layers and that no individual structure (the inner lining alone or the muscle alone, etc.) can undergo injury while the others remain untouched. This fact was suggested some time ago by Professor Krehl, of Heidelberg, and it is universally recognized now that infections leave their anatomical traces in every structure of the heart simultaneously. Knowing that infections are the commonest cause of heart disease, we can not overestimate the importance of this finding. The advances made in all fields of scientific cardiac research have been summed up recently in a group of monographs and larger works. Professor Mönckeberg and others, in a monumental cooperative work, have put before us all angles of the pathological anatomy of the heart, a task which has been carried out for the physiology of that organ by Professor Tigerstedt and for the normal anatomy by Dr. Tandler, of Vienna.

Clinicians, if they set themselves scientific ideals, require exact knowledge of the working of each organ: they wish to know every function of the organ or system under investigation and they must have quantitative data. Results of physiology are translated into terms used in bedside work and adapted to give the clinician the quantitative information concerning each function which he requires. In this effort, primary attention has been given to the so-called functional diagnosis. The methods furnishing handles for such a functional diagnosis of the heart are ever increasing in number. We may state some of them briefly. One is the Röntgen ray. Here one of the most original and fruitful investigators is Dr. Vaquez, of Paris. Exact estimations of the size of the heart do not confine themselves any more to an area, a two-dimensional system, but cover the organ in all three dimensions in more or less successful attempts. Moreover, very recently, Dr. Cohn, of the Rockefeller Institute, introduced a kinematographic method registering the movements of the borders of the heart-shadow. Thus, the X-ray method becomes a true dynamic and physiological method, following the movements of a restless and ever-moving organ, and does not merely furnish anatomical data. Another method of importance for the clinician is the electrocardiograph of which I have spoken above. A third is the estimation of the blood-pressure which branches out into various elaborate collateral methods. A fourth is the microphonic or optic registration of the heart sounds. A fifth endeavors to estimate the rapidity of the circulation, the flow of the blood and is closely related to methods aiming to evaluate the output of the heart per each stroke or per time unit. The most recent and promising contribution in this particular field comes from Drs. Henderson and Haggard, of Yale University. It would be easy to enumerate indefinitely the ways and means of approach which are designed to clear up one or another phase of the circulation in the living human being, in which after all physicians and public are primarily interested. There are great difficulties in the precise evaluation of the function and work of the heart. These difficulties are due first of all to our inability to discriminate between the individual functions and to put each one of them on a strictly quan-

titative basis. Should this at last be achieved, the next step would be to integrate them up into the complex system of operations known now as heart-function. And it might be stated here that this course could be followed more readily should there be a great cardiologic center in which all effort is concentrated. A center like this ought to provide facilities for anatomical, physiological and clinical studies, all of them tuned together, where the viewpoints in research would be complementary, instead of being mutually exclusive and where every clinical observation and anatomical finding would be supplemented by physiological experiment. The best place of course for such a central station would be a large city, with abundant available material of all sorts.

Where and what are the outstanding problems for the future? I have mentioned that of functional diagnosis and the difficulties with which it is fraught. Another one is the famous question of the reserve power of the heart and its adaptability to the varying needs of the organism. The determining factors of this reserve power are not exactly known. Of chemical factors, there has been some indication that grape sugar might be one. These conditions, however, are very intricate and hang together with fundamental and remote biological problems. Again another problem is that of the "peripheral heart": the rôle of the arteries and capillaries in the propulsion of the blood, their action in counterbalancing, evening out and supplementing the work of the heart itself and so on. We shall be compelled to study the circulation as a whole without detaching arbitrarily one solitary phase of it.

On the practical side, doubtless the problem of the greatest importance is that of endocarditis. As I have already mentioned, it is now universal knowledge that the larger part of heart disease and certainly nearly all of it in young people is due to infection. Infection originally of an everyday and common character—tonsilitis, dental infection, etc.—begets an inflammation of the lining and musculature of the heart and with this commences the long train of chronic disease involving much suffering. Not only that it precipitates, but infection also maintains and aggravates this inflammation, interferes with the reserve power and adaptability of the muscle which is trying to grapple with the obstacles set by diseased valves. It is not fatigue and exercise but recurring infections which jeopardize recovery and cripple the cardiac patient again and again. This problem appeals first to the bacteriologist, who will try to establish the causative microorganisms of diseases which notoriously accompany acute cardiac infections, *viz.*, rheumatism of the joints, hoping thereby that this will lead to the discovery of some specific organism being responsible for the cardiac infection itself. It seems probable, however, that the germs in question are not very specific, but that they belong to the great class of strepto- or staphylococci. Furthermore, it seems likely that the center of the problem lies not so much in the identification of the germs but in the discovery of certain chemical conditions which render cardiac tissue less resistant to their attack in some cases of ordinary infections than in others. The field here belongs to the experimental pathologist with his perfusion method and chemical as well as physico-chemical technique. Secondly the problem appeals to the specialist in public health whose task is the prevention of these ordinary everyday infections by means of education, dispensaries, dental supervision and periodic health examinations. Insurance companies could very well take a hand in the campaign. It is well to realize that about one sixth of the world's total mortality is due to cardiac disease and it is

equally well to realize that the majority of this enormous number concerns young and otherwise healthy people whose untimely death is great economic loss and inestimable damage to the community. The tragedy of acute cardiac infections can and should vanish from the earth.

There is another great contingent of cardiac mortality and that is due to arteriosclerosis. Much has been said about the dietary factors concerned in the production of this disease, but nothing definite has been attained. We should be more careful about blaming our heavy meat diet for its prevalence, knowing that Sir Marc Armand Ruffer has found arteriosclerotic changes in mummies dated from the times of the twentieth dynasty. The same finding should also be a warning against the idea that neurasthenia, occasioned by a strenuous modern way of living, is a fundamental factor. Anatomical research has revealed many an interesting point about this disease, nevertheless more fruitful results may be expected from an entirely different line of inquiry into the causes of arteriosclerosis. The suprarenal glands with their constant pouring of blood-pressure raising adrenalin into the blood-stream suggest conditions in which the production of this hormone might be increased. Here is a real possibility of discovering links between certain nervous conditions, like some forms of neurasthenia and arterial disease, for the influence of the nervous system upon the various functions of the adrenal glands has been conclusively shown, amongst others by Professor Cannon, of Harvard. This task should be divided between the statistician and the experimental pathologist.

It is a long cry indeed from Harvey to the wonderful laboratories of the maturing twentieth century, from the methods of simple observation to exact physical and mathematical analysis. Very much has been done in cardiology and our final conclusion must acknowledge that the materials are at last assembled with which to reap great results. These are now, to a great extent, hanging in the air, being in the second stage of knowledge according to Plato's "Theaethetus," for their connections are more or less known and the tasks are entirely clear. Thus it may be expected that the next half century will witness their realization.

RADIO TALKS ON SCIENCE[1]

EXPLORATION OF THE POLES OF WIND ON OUR PLANET

By Professor WILLIAM HERBERT HOBBS

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THE present year is to be marked by an extraordinary revival of interest in the exploration of the Arctic. One of the great Arctic explorers stated to me some weeks ago that he already knew of thirteen Arctic expeditions in preparation, some of them not yet made public. These expeditions represent several purposes, and a number of them have for their main objective the exploration of the world's largest and most inaccessible unexplored area off the coast of Alaska in the direction of the North Pole. Effort should not be relaxed until this blank area upon the map of the world has been made known.

Studies in other regions already partially known can make exceedingly important contributions upon fundamental problems of science which can be satisfactorily solved only within the regions explored. One such region is that of Greenland to the eastward of the great unknown area north of Alaska. If certain studies in Greenland, for instance, are successfully carried through, they will be of great practical as well as scientific importance, for what I have in mind is nothing less than the careful observation of the origin of the storms of the North Atlantic and Europe in the cradle where they begin their existence, and in the same early stage of their careers the icebergs which are such a peril to the navigation of Atlantic waters. Northern storms and northern icebergs, the great perils in the navigation of the north Atlantic, alike have their breeding ground in the great flattened dome of ice which like a gigantic white cap covers almost the entire continent of Greenland—an area fifteen hundred miles in length, with an average breadth nearly one half as great.

This vast area, which in form most closely resembles the back of a watch, is, with the exception of the even larger but similar Antarctic ice-cap, the most perfect desert to be found anywhere on the face of the globe. It is a desert waste at an average elevation of nearly two miles above the sea, where one travels for days on end and sees only the level surface of the snow beneath and the sky above, and over this vast expanse no trace of life has been found. Such a snow-mantled ice surface has little in common with that of the frozen Arctic sea on which the late Amundsen and MacMillan expeditions attempted to land with seaplanes, but without success. This sea-ice surface is that of a jumbled collection of ice-rafts or ice-floes which are joined to each other by ridges of ice hummocks, each floe too small to provide a safe landing field. The unique hope for a safe landing with a seaplane is to discover one of the lanes of open water which occasionally appear for a brief interval to suddenly close accompanied by terrific grinding pressures and the formation of more pressure ridges.

By contrast, the surface of the ice-cap of Greenland, except within a relatively narrow and steep marginal zone, is almost as flat and even as a ballroom floor,

[1] Broadcast from Station WCAP, Washington, D. C., under the auspices of the National Research Council and Science Service and the direction of Mr. W. E. Tisdale.

and it stretches away for hundreds of miles. Lieutenant Commander Byrd, of the last MacMillan expedition, flew for about forty miles in a Loening amphibian plane over the borderland of the ice-cap in northern Greenland, and he reported that except in the neighborhood of the edge he could have landed anywhere without difficulty.

The coldest place on the globe is not, as popularly supposed, the North Pole. The winter temperature at the North Pole is certainly quite warm if compared to that of Siberia or southern British America. In fact, throughout the long winter season at points along the coasts of these barren land areas the winds which blow from the direction of the North Pole are the warm ones, while those from the south are correspondingly cold. The coldest place *where temperatures have been measured throughout the year* is located in Siberia, but it is certain that in the heart of Greenland and of the Antarctic the winter cold is much more intense, for even in the midst of summer the mid-Greenland air temperatures have been found to be more than 30 degrees below zero. It is therefore of prime importance to find out more about the air conditions over Greenland. One of the several polar expeditions which are being organized this year, that of the University of Michigan, has been planned to study carefully the meteorological conditions of this very critical and significant area by establishing and maintaining for a year a number of weather observing points connected by short wave length wireless communication.

It is this intense cold of the interior area of Greenland which is responsible for the havoc-making storms that issue from its margin. Winds are due to differences of temperature at different places upon the surface of the earth. Along the belt of the equator there is, so to speak, a great furnace, and within this belt the heated air rises and passes off at high levels northward and southward toward the poles. The intensely cold ice-caps of Greenland and the Antarctic are by contrast the refrigerators of the earth above which the high currents of air which have traveled from the equator are sucked down and drained off as though through a gigantic shaft, and from the bottom of this shaft they are poured out in all directions toward the margins of the ice-cap to make their return to the furnace on the equator, thus making of our air circulation a complete circuit.

The mechanism by which this polar refrigerator of Greenland operates is in part at least quite simple. As the air immediately over the surface of the cold ice-cap is cooled, it contracts and becomes heavier and so slides outward upon the surface of the dome for the simple reason that a dome everywhere slopes toward its margin. Such a draining off of the air from the ice-cap with the indraft above and the downdraft about its axis, is called the Greenland glacial anticyclone, and it constitutes the northern wind pole of the earth as the Antarctic does the south pole.

Outside the ice-caps of Greenland and the Antarctic the weather at any place may be said to be imported through the agency of the migrating whirls in the atmosphere known as "lows" and "highs"; but by contrast the weather over the ice-caps may be described in terms now familiar to every one as "home-brew."

The discoverer of the law of constant down-slope winds above the Greenland ice-cap was Admiral Peary, at the time when he made his remarkable sledge journeys across its surface in 1886, 1892 and 1895. He was much surprised to learn that, quite independent of the indications of his barometer, the wind always blew nearly in the direction of the slope of the ice surface. If he was climbing a slope the wind was sure to be in his face, and if descending the wind

always came from behind him. The effect was the same as though a liquid were flowing by gravity off the dome-shaped surface toward the sea about its margin.

One may produce such an anticyclone on a very small scale by a very simple device. In a glass globe such as is in common use for gold fish a copper tank of domed form is placed, and into this tank ice-water can be poured. On a perforated platform above the tank is placed a lighted cigarette. When the tank is empty the smoke from the cigarette curls upward in the usual manner, but so soon as ice-water is poured into the tank the smoke is observed to be sucked downward in a whirling vortex and to slide downward and outward on the domed surface.

The most important feature of the Greenland anticyclone, and that which produces the great storms, could only be illustrated by an experimental device on the same vast scale as the ice-cap itself. We are living in an automobile age and from our experience with inflated tires we all know that air is warmed when compressed or cooled when allowed to expand. As the air on the glacier surface slides downward toward the margin it is compressed and warmed under the increased pressure from overlying air, and when this air in sliding outward has attained hurricane velocities it is so rapidly warmed as to stop its own motion which was due entirely to the fact that it was previously being cooled. That small element of the hurricane which finds its way down to the fjords on the borders of Greenland and is there recorded at the Danish weather stations ends in a brief warm and stifling atmosphere like that characteristic of the "chinook" along the east slopes of the Rocky Mountains, and both are due to the same cause. At the higher levels the storm passes outward with its full velocity. The "lows" on their way eastward from the United States to the coast of Europe, if they pass Greenland before the storm has developed over the ice-cap, reach Europe in a dying condition because they have expended their whirling energy on the long journey across the Atlantic. If, however, they pass into the neighborhood of Greenland when the storm from the ice-cap is in full swing, its energy is poured into the "low" and transforms it into a storm the violence of which depends directly on that of the hurricane over Greenland. The storms which a month since caused such losses of life and property and brought such heroic American seamen into deadly peril of their lives, are examples of what the Greenland anticyclone is capable of engendering.

Such knowledge as we now have of the exact dates when storms have passed outward from the margins of Greenland, and of the dates of arrival of violent storms in western Europe, show that several days must elapse from the time when the winds pass outward from Greenland before the storms arrive on the European coast. It is confidently expected that with wireless equipment which the new weather observing stations will have in Greenland, forecasts of the Atlantic and European storms can be made so as to give warning one or more days in advance.

HOW EARTHQUAKES ARE LOCATED

By Commander N. H. HECK

U. S. COAST AND GEODETIC SURVEY

When an earthquake occurs on land, we usually know before long just where it occurred and where the greatest amount of damage was done or where it was felt with the greatest intensity. This is not always the case and some-

times even when the reports are complete and an investigation has been made, it is hard to tell where the effect was the greatest. The Quebec earthquake of February, 1925, was a case of this kind. There are, besides, many parts of the earth where communication is very uncertain. For example, no details were known of the great earthquake in Central China in 1920 till a visit to the region some years later by a Gobi Desert expedition, though seismologists knew that it had occurred and its approximate position and intensity.

If there are difficulties in knowing where an earthquake occurred on land, what can we expect to do with the greater number beneath the sea? Occasionally a ship happens to be directly above the place where it occurred, or in the near vicinity, and at times great seismic or tidal waves sweep in on the shore. If these come from a great distance they are not much aid in locating the earthquake. Sometimes a very great earthquake, the waves from which go entirely around the earth, occurs beneath the sea; and with no ships in the region and no seismic sea wave no human being ever received through his unaided senses any knowledge that there was an earthquake. This does not mean, however, that such an earthquake is not located.

Every few weeks a statement appears in the newspapers that the seismograph station at Georgetown, Harvard or Honolulu reports that an earthquake occurred at a given distance; for example, 1,950 miles from Georgetown. Later a further report states that as a result of reports received from various observatories through "Science Service," experts of the Coast and Geodetic Survey locate the earthquake which occurred at 9:49 P. M., at latitude 12° north, longitude 89° west, or just off the coast of Salvador, Central America. Remember that this is done, usually, within twenty-four hours after the earthquake occurs, and that it could be done in a few hours if it were not for communication delays. Even if we know that an instrument called the seismograph makes a record called the seismogram, the matter still remains rather mysterious.

It is not easy to explain this, even with diagrams, and without them it is still more difficult, but I hope that by making comparisons from time to time with more familiar things I may be able to give you some picture of the process by which an earthquake is located. Many of you know that pendulum clocks sometimes stop during an earthquake, while others nearby keep running, but with a changed rate, and that bells ring when near enough to the center of disturbance. In both cases it is because the support moves and the clock pendulum and bell clapper, since they are pendulums, take a different motion from that of their own support. The instrument known as the seismograph is based on the simple pendulum, though in a modified form, for scientific reasons. Without going into detail, a type of pendulum is so delicately balanced that if its support is shaken, even to an extent imperceptible to our senses, by waves coming through the earth, the motion will be recorded. It will be different from that of the earth, and yet, with good instruments, will have a definite relation to the earth's motion, which can be deduced by mathematics. In practice, a pointer connected with the pendulum moves back and forth on a sheet of paper covered with lamp-black so that a trace is left somewhat resembling that of a pencil on paper, but much finer and more clear cut. The smoked paper is on a revolving drum turned by clockwork. When there is no earthquake or other disturbance the pointer makes a straight line, and other mechanism makes a mark every minute. This makes it possible to note and measure the exact instant that the pointer departs from the line.

When an earthquake occurs, the pointer starts swinging back and forth, and since the paper is moving, it makes a curve which looks somewhat like a series of waves coming in at the seashore. Every one has noticed that sea waves differ in height, with now and then a very large one, and some time between these very small ones. The same thing is true of the waves on the smoked paper record, which is known as a seismogram. The time between the arrival of successive crests of sea waves is called the period of the waves, and the same term is applied in the case of the seismogram. Briefly, when the seismologist finds an earthquake record on the seismogram, he looks for the first jog or departure of the pointer from the straight line and measures the time. Then, as the waves keep coming in, he looks for places where they change in height or period, and notes these times. Bear in mind, then, that we can get from a seismogram the time of arrival of the first wave from an earthquake and also the time that different types of waves arrive, since the pointer shows the changes in the wave motion which is arriving through the earth.

Some of the best seismographs have photographic recording, but the principle is the same, though the record can not be seen till developed.

You know what happens when a stone is thrown into a pond. Waves go out in concentric circles and spread till they reach the edge of the pond. In the case of the earth, which is a solid, the important difference is that three different types of waves, instead of only one, go out when there is a disturbance. Suppose that an earthquake occurs near Japan. Three main sets of waves go out. Considering the waves that arrive at Washington, the first and second take the direct path through the earth, passing about 1,400 miles below Mt. McKinley, Alaska, where they are at the greatest depth below the surface. The second is a different kind of a wave from the first and travels slower and therefore always arrives later. The third wave follows the surface of the earth and arrives last, though usually it causes the largest waves on the seismogram. The speed of the waves in the case given are, respectively, about seven and one third, four and two and one third miles per second. In getting the distance we are particularly concerned with the first two sets of waves, because it is easier to measure their time of arrival accurately, and if this can be done we need nothing more. The record then gives the exact time of arrival. From this we can get both the distance and the time that the earthquake occurred. For example, if the first wave arrived at 3–05–45 and the second at 3–17–26, a minute's glance at a table shows us that the earthquake was 6,830 miles away and that it occurred at 2–51–55.

Let us look at this another way. Many a schoolboy has had to work out a problem like this. Two trains leave an unknown point, A, and proceed at a constant speed. At a point, B, the first train, traveling sixty miles an hour, passes at 4:30 P. M., and the second, traveling forty-eight miles per hour, passes at 4:42 P. M. It is not hard to show that A is forty-eight miles from B and that the trains left A at 3:42. You may ask how we know the speed of travel of the waves. This can be obtained from any station, for a given earthquake, provided we know where and when the earthquake occurred, without using the record at the station under consideration. Collection of such data from a large number of cases and theoretical studies makes it possible to work out the necessary tables.

Now suppose that we have the distance of the earthquake from three stations. How can we get its position? The first thing is to know whether the distances are correct. We assume that if the time of occurrence of the earth-

quake is approximately the same as figured from all three records, we may accept the distances as given. The next step is to take a globe such as is used in teaching geography in schools and mark off on a tape every hundred miles or kilometers to the scale of the globe. Suppose that we have an earthquake 1,950 miles from Washington. We set the zero of the tape at Washington and note where the 1,950 mile mark comes. We can swing a complete circle, but this is not usually necessary because we nearly always know at what place on the circle earthquakes are likely to occur. If a circle from another station crosses in this same region, the approximate location is fixed. Then we swing a third circle from another station and if the circles intersect in a point we know where the earthquake occurred. Usually, for various reasons, the circles do not intersect in a point and then we plot distances from still other stations and finally select the most probable point.

There is another consideration. If we try to locate an earthquake in the Pacific Ocean north of Australia, from stations in the eastern United States, we will get a line for the earthquake and not a point. As an illustration, suppose we try to locate on a map a point 120 miles from Washington, 120.1 from Rockville, Maryland, and 120.2 from Alexandria, Virginia, we get only a line; but if we add that the point is thirty miles from Philadelphia, we arrive at once at a definite point. In other words, the circles should intersect at as large an angle as possible.

If we have reports from a number of well-placed stations, any earthquake sufficiently severe to be recorded at them can be located. The method that has been described is used, though of course with certain mathematical adjustments, in the final location of the earthquakes. Such final locations are published, after several years, by the Dominion Observatory at Ottawa, Canada, and the final location, using all available stations throughout the earth, by the Central Seismological Bureau at Strasbourg, France. The Coast and Geodetic Survey publishes preliminary determination for all severe earthquakes occurring or recorded in the United States or the regions under its jurisdiction, except frequent local shakes in several regions. These usually appear within six months after the end of the quarter.

The immediate location of earthquakes is done in the same manner; the only difference being that the seismograms must be interpreted in haste and the results sent in by telegraph. The Coast and Geodetic Survey has found it possible, however, to locate the earthquakes with satisfactory accuracy, since "Science Service" has made it possible to get reports for a large number of well-scattered observatories, including those of the Jesuit Seismological Association. With a large number of records available difficulties in interpreting individual records are not important.

In addition to satisfying legitimate public curiosity, the location of earthquakes is important for property owners, insurance companies, engineers and others. Incidental to the location of these earthquakes we learn something about the interior of the earth, and it seems not unreasonable that in the future some of the energy that has been put into the exploration of the earth's surface should go into the investigation of its interior.

Continued public interest in earthquake study is the one thing needed to make possible the solution of the problem involved. We can not change earthquakes, but just as we have done away with many of the unchanged dangers of the sea by learning how to meet them, we can do away with most of earthquake destruction of life and property by knowing earthquakes.

A BOTANICAL SHRINE

By Professor JOSEPH CHARLES ARTHUR

PURDUE UNIVERSITY

ALL the scientific world respects the name of Linnaeus, the father of botany. He was accorded to be a great man during his lifetime, not only by scholarly persons and societies all over the world, but by potentates and the ruling class. He was buried in the ancient cathedral at Upsala, and a monument erected to his memory. His death was regarded in Sweden as a national calamity. The whole University of Upsala, of which he was rector for some years, went into mourning, and King Gustav in his annual address to parliament lamented his death and ordered a medal struck in his honor. Although his chief delight was botany, he was almost equally learned in medicine, the various branches of zoology and in mineralogy and geology. In the great bulk of his contributions to the world's knowledge probably no one item stands out more prominently than his substitution of the familiar two-word or binomial method of naming plants and other natural history objects for the previously prevalent method, which Rousseau characterized as "a long tirade of Latin names which sounded like a con-

OLD BOTANIC GARDEN AT UPSALA

VIEW ALONG CENTRAL WALK AND LILY-POND; AS IT APPEARED IN 1925.

HAMMARBY RESTORED TO APPEAR AS IN LINNAEUS'S TIME

EXCEPT FOR THE TALL TREES; RESIDENCE AT CENTER, STORE ROOMS UNDER TURF-ROOF AT SIDE, AND BARNS OPPOSITE.

juration of hobgoblings." His career ended at the time the United States became an independent nation. When knighted in 1753, following a general custom, the form of his name was changed to Linné. Both forms of the name have continued in use. So much, with much more, is common knowledge.

With Dr. F. D. Kern, I visited Upsala during August, 1925, to discuss some exceedingly modern problems in botany and with only a mild academic interest in the man who lived there over a hundred and fifty years ago. But we found the very atmosphere of the place saturated with the memory of one of Sweden's greatest characters, and the most distinguished son of this renowned seat of learning. We were taken to the old Botanic Garden, a hundred years old even when Linnaeus became its director. It is on the Linnégatan and is maintained by the city as near as possible in the condition it was when Linnaeus was in charge, even to the same kinds of plants. One of the buildings houses mementoes and interesting objects of his time. Any person, botanist or otherwise, would be charmed with the spot. As a botanic garden or public park it would, in fact, do credit to many a university city in America. The new Botanic Garden is some distance away, far larger and with substantial modern buildings. We were shown the Linnaean memorials in the cathedral, a small herbarium prepared by Linnaeus, the larger part of his original herbarium being in London, and many other reminders of the great man. Having completed our botanical discussion and taken a hasty survey of the interesting features of this historical center of Sweden, and for the last five hundred years or more the focus of its intellectual life, we signified our readiness to depart.

There was one spot in the vicinity that our host, Dr. Juel, urged we ought not to miss seeing. Hammarby, the summer residence of Linnaeus during the last twenty years of his life, lies seven miles away. A large Packard car, serving as a taxi, took us over a country road, past cultivated lands, to a plain farmhouse, situated on a rise of ground that permitted an extensive view. Not far away could be seen the spot where in very ancient times the kings of Sweden presented themselves before the people and swore to uphold the laws.

The Linnaean homestead has been restored with scrupulous care to its former condition. The structures are plain and crude, as might be expected upon a farm, at that time belonging to a family never well supplied with cash. The rooms contain, beside much furniture of the old days, a surprisingly large number of souvenirs, memorials, paintings, busts, books, manuscripts and other objects pertaining to Linnaeus' career. In front of the house a large flower garden was a mass of color at the time of our visit, the plants being as far as possible the very kinds tended by the master.

But we did not fall under the full spell of the place until we climbed the small hill at the rear of the house. Here is a building about forty feet square, called "The Museum," where Linnaeus kept his books, herbarium, collections of shells, insects and minerals, now mostly in possession of the Linnaean Society of London. We saw the chair where he sat, with its rest for books and specimens when delivering his talks, and the three benches for his audience. In pleasant weather, and especially if the audience was larger than usual, he placed the chair in the doorway and talked to his hearers outside. Thitherward journeyed scholars and men of distinction from all over the world to listen to his lectures. At one time came Sweden's Crown

MONUMENT TO LINNAEUS AT STOCKHOLM

AT THE BASE OF THE PEDESTAL ARE FIGURES REPRESENTING BOTANY, ZOOLOGY, MINERALOGY AND MEDICINE.

Prince, afterward King Gustav, and at another my lord Baltimore of American fame. One of his hearers has recorded that "science streamed with peculiar pleasantness from his lips; he spoke with a conviction and perspicacity which his deep penetration and ardent zeal imparted to him; and it was impossible to hear him without attention, and without participating in his enthusiasm." This peculiar fascination still lingers about the place. Botanical societies hold meetings here, and botanical pilgrimages are numerous. It has become a veritable shrine, where homage is done to the memory of the father of botany. We descended the hill in a pensive mood. In the wild garden, now grown up with trees, many dating from Linnaeus' time, we were served cakes and tea and heard the history of the place recounted. Reaching our automobile, our excursion into botany's early days ended, and the modern world again claimed our attention.

FUNDAMENTALISM

By Dr. PRESTON SLOSSON

God of the star-swarm and the soul,
The conscious Will that made the world
From ether drift and cosmic dust,
Such is the God we know and trust.

Our partial pictures of the Whole,
Our demigods from heaven hurled,
Our idols in their chapel nooks,
Our gods of stone, or wood—or books—

Forgive them all! We are but men,
Our thoughts must go a homely road,
We build as children in their play
Our frail theologies of clay.

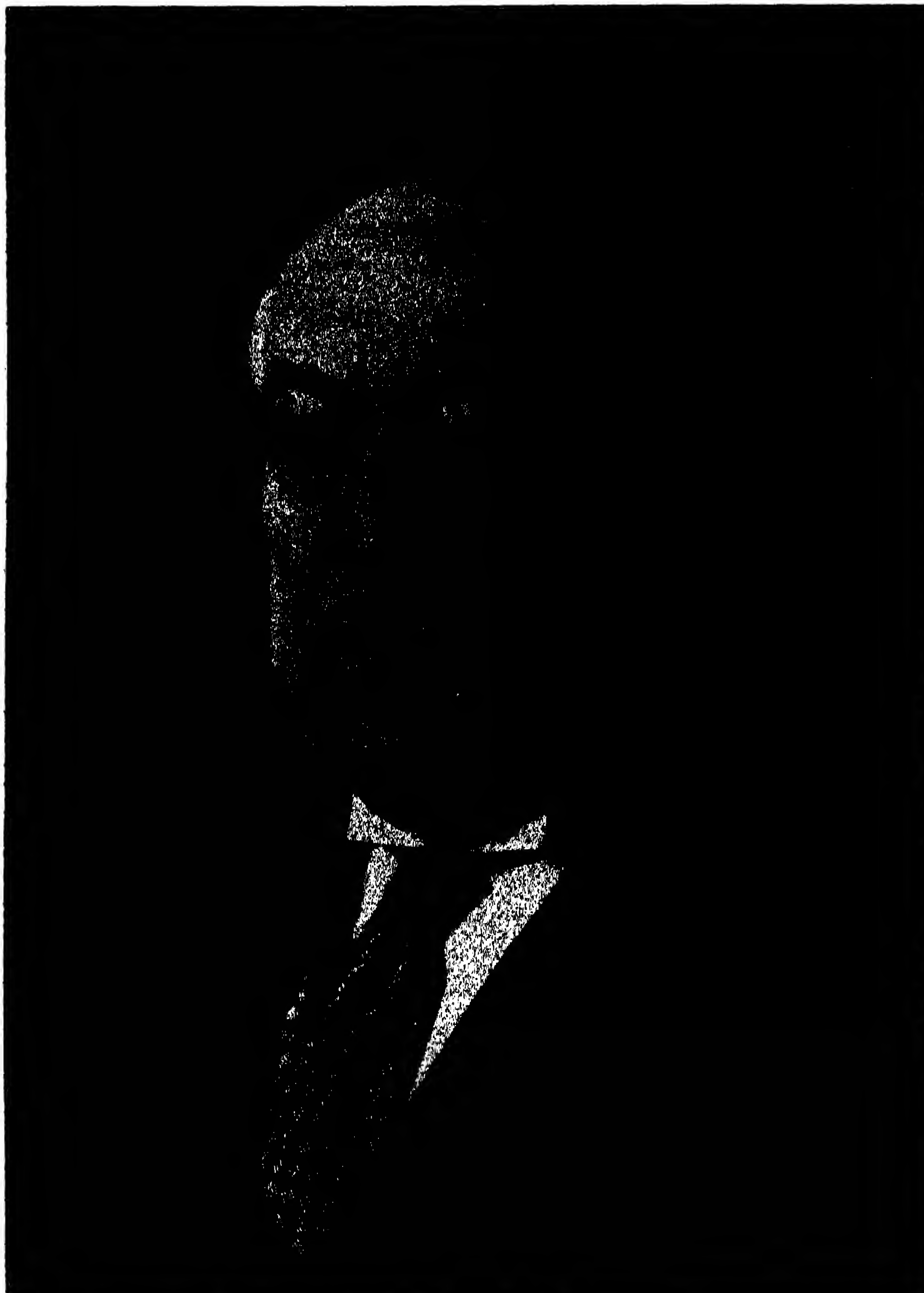
Children will grow. More wisely then
Our race will tread a steeper road,
Lifting our thoughts from earthly sod,
From Threshold to the Throne of God.

No sin it is for childhood's mind
To lift a candle as the sun,
The great is imaged in the small
Better than never seen at all.

But *this* is sin: To choose to blind
The sight to light that men have won,
Deny the truth that has been taught,
Fetter the Godward searching thought.

Creation's magic is too great,
They fear to view it open-eyed,
They wish the world a smaller place,
Eternity a shorter space.

Their fear is swiftly turned to hate,
Truth dreaded soon is truth denied,
They call on Caesar to resist
God's fearless saint, the scientist.



PROFESSOR CHARLES EMILE PICARD

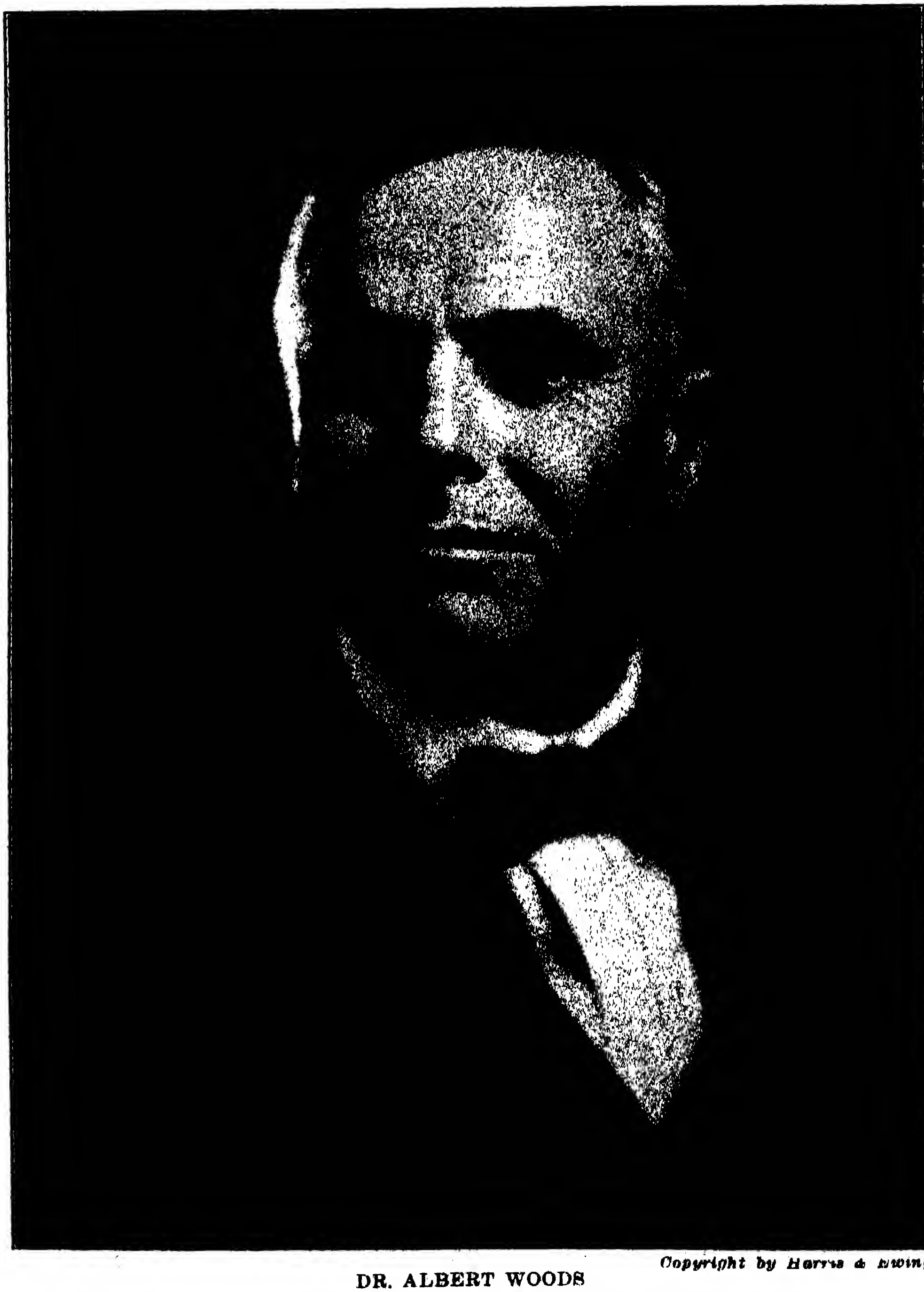
THE PROGRESS OF SCIENCE

PROFESSOR CHARLES EMILE PICARD

Professor Charles Émile Picard, who was received into the French Academy on March 11 and thus became one of the "forty immortals," may be regarded as the most eminent living mathematician. He is about seventy years old, having been born in Paris, July 24, 1856, and he has been permanet secretary of the Paris Academy of Sciences since 1917, when he was elected as successor to Gaston Darboux. In 1899 he gave three lectures at Clark University on the development during a century of some fundamental theories in mathematical analysis, and in 1904 he lectured, before the section of algebra and analysis at the St. Louis International Congress of Arts and Sciences, on the development of mathematical analysis and its relation to certain other sciences. While these lectures had a historical character they exhibited also new ways in which science tends to develop, and the last one emphasized the relations existing between analysis, geometry, mechanics and mathematical physics. All of them were combined and appeared in 1905 in the form of a book of 167 pages.

During the latter visit to the United States he, together with Henri Poincaré, went to the Pacific Coast, and he has thus become personally acquainted with a considerable number of American men of science, but he is probably best known to American mathematicians and physicists on account of his "Traité d'Analyse," which has for many years been regarded as one of the best text-books for the student who is just beginning his graduate work in mathematics, and it is so attractively written that the late Felix Klein, in his "Elementarmathematik" described it as reading like a well-written exciting novel. In fact, Picard's writings, as well as his lectures, are noted for clearness and for the new light they throw on relations between subjects which were not supposed to have any direct connection. He has a very high standing both as a teacher and as an investigator. Personally, he is quite independent and is inclined to state what he regards as just without any care as to whether his conclusions are agreeable or disagreeable to his hearers.

While he is interested in philosophical and historical questions he is more interested in making real scientific advances than in the discussion of points which are and probably will remain unsettled. He has on various occasions directed attention to the great difficulty which the history of science presents in view of the unreliability of many of the published statements relating thereto. He believes, however, that more attention should be paid to this history in our scientific courses of instruction in view of the fact that scientific advances represent the greatest intellectual achievements of the human race. The wide scope of his mathematical investigations is partly exhibited by the fact that his name is now associated in the mathematical literature with fundamental modern developments in various fields, as may be partly inferred from the following well-known mathematical terms: Picard's Theorem, Picard's Equation, Picard's Group, Picard's Surfaces and Picard's Integrals. He is a member of a very large number of scientific organizations in various lands. In America he was elected in 1903 as a foreign associate of



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DR. ALBERT WOODS

Who has been appointed director of scientific work in the United States Department of Agriculture by Secretary Jardine in succession to Dr. E. D. Ball. Dr. Woods was President of the Maryland State University and had previously been head of the Department of Agriculture at the University of Minnesota. He is distinguished for his contributions to plant pathology.

the National Academy of Sciences of the United States, and as an honorary member of the American Academy of Arts and Sciences, Boston. In 1910 he was elected an honorary member of the American Philosophical Society, Philadelphia. While his health has not permitted him in recent years to travel as much as formerly he is still an active writer.

G. A. MILLER

UNIVERSITY OF ILLINOIS

THE INTERNATIONAL EXCHANGE SERVICE AND GERMAN SCIENTIFIC INVESTIGATION

As a result of the distressing economic conditions in Germany since the World War, German scientific investigation has been seriously hampered. The Smithsonian Institution of Washington, D. C., through its International Exchange Service, has undertaken to aid in every possible way the re-establishment of German scientific activity, the cessation of which would be a loss not only to the German people, but to the whole world.

Many thousands of publications gathered by various American organizations have been forwarded to Germany through the Smithsonian Exchange Service since the close of the war. By far the largest and most important of these sendings has recently been received in Germany. It consisted of a collection of American periodicals, weighing 13,000 pounds, packed in 61 large boxes. It was received by the Smithsonian Institution from the Library of Congress and forwarded through the International Exchange Service to the Amerika-Institut in Berlin, an establishment organized to promote the cultural relations between Germany and the United States and also to conduct the German Exchange Agency.

The Amerika-Institut was itself in danger of being compelled to suspend operations at the close of the war on account of lack of funds, but fortunately the Smithsonian Institution succeeded in procuring sufficient financial aid to enable that institute to carry on the exchange work for a period of two years, after which it was again able to maintain itself.

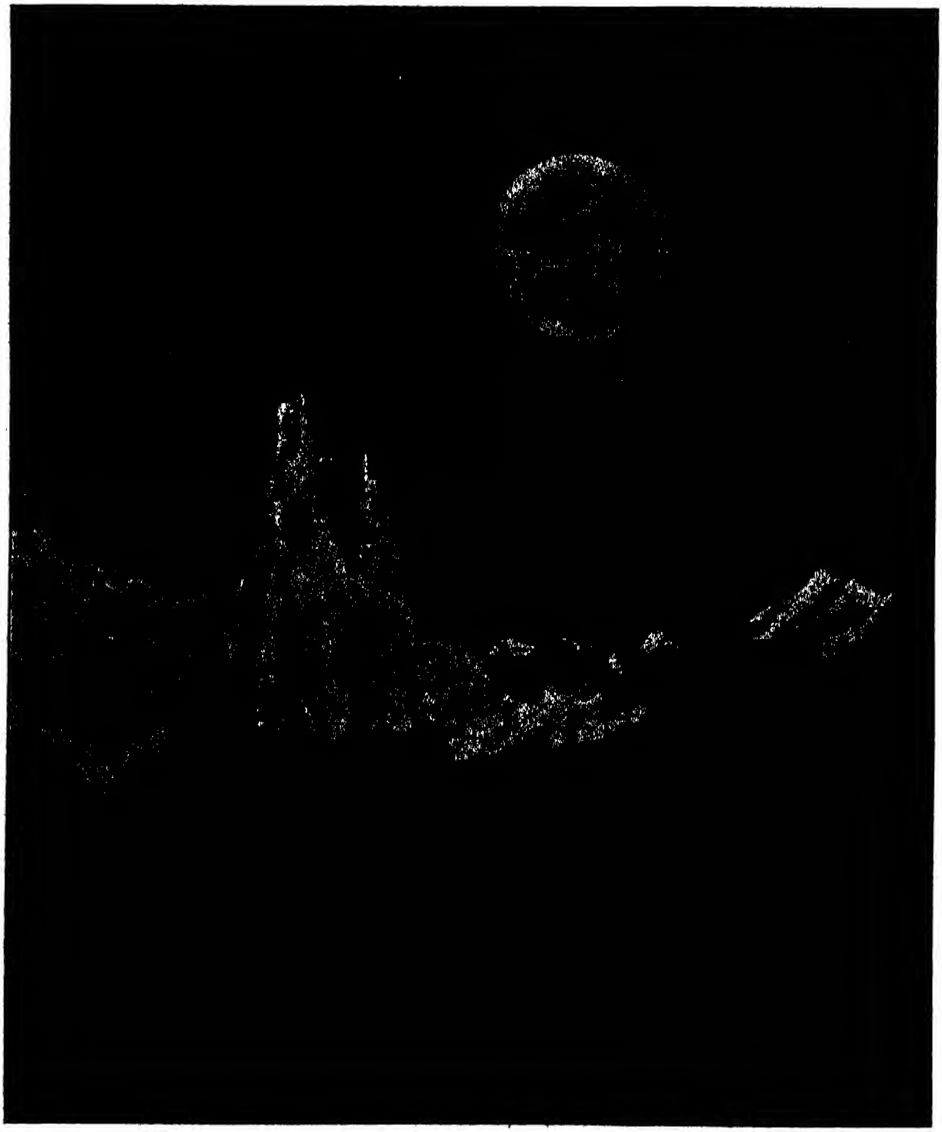
A letter of appreciation of the latest gift of periodicals has just been received by Secretary Charles D. Walcott, of the Smithsonian Institution, from the Notgemeinschaft der Deutschen Wissenschaft in Berlin. This letter indicates the value which the German scientists place upon scientific literature from this country, especially in the present circumstances.

"We shall utilize the periodicals," says the letter, "in completing gaps which still exist in German libraries, for which purpose the scientific and technical periodicals sent to us are of great value. The other more popular publications were also of interest here, as hardly any German library appears to have received them heretofore. It is a pleasure to me to thank you sincerely for the trouble which the matter has given you."

The Notgemeinschaft was founded in 1920 at the instigation of the Berlin Academy of Sciences for the express purpose of trying to avert the destruction which was threatening to overtake scientific inquiry in Germany because of the economic conditions growing directly out of the war.

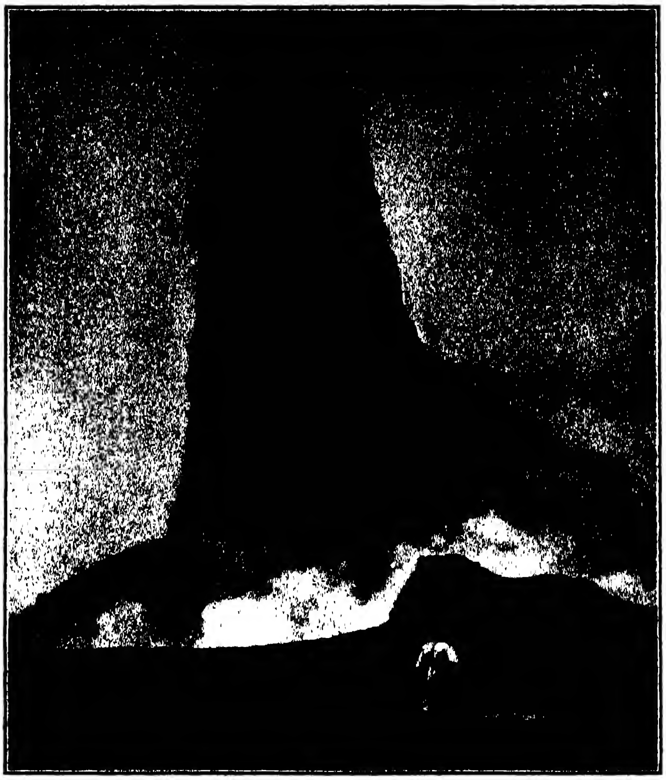
One of the greatest services which the Smithsonian Institution renders to science is the distribution of scientific literature to foreign countries and the collection of such foreign material for American scientific libraries.

When increased funds are available, the institution hopes to enlarge this service to foreign and home institutions. By this method scientists everywhere are kept informed of each other's work and



A LUNAR LANDSCAPE

SHOWING THE EARTH IN THE SKY, THE OBSERVER BEING LOCATED IN THE RUGGED LUNAR CRATERS NEAR A SPINE THRUST FROM THE CRATER FLOOR. THE EARTH IS REPRESENTED AS IN THE MONTH OF JUNE WITH THE ATLANTIC TOWARD THE OBSERVER. IT IS PASSING THROUGH THE CONSTELLATION SCORPIO, THE FIRST MAGNITUDE STAR, ANTARES, APPEARING NEAR THE POINT OF THE SPINE. MARS, NO REDDER THAN ANTARES, IS SEEN NEAR THE TOP OF THE CANVAS. PAINTED BY HOWARD RUSSELL BUTLER, N. A., WITH THE COOPERATION OF PROFESSOR HENRY NORRIS RUSSELL, DIRECTOR OF THE HALSTED OBSERVATORY AT PRINCETON. THIS PAINTING, TOGETHER WITH THE AURORA SHOWN ON PAGE 470, WAS EXHIBITED AT THE OPENING ON MARCH 24 OF A PRO-ASTRONOMICAL HALL AT THE AMERICAN MUSEUM OF NATURAL HISTORY. WE ARE UNDER OBLIGATIONS TO DR. G. CLYDE FISHER, IN CHARGE OF ASTRONOMY, FOR THESE PHOTOGRAPHS WHICH WERE TAKEN BY HIM.



CONE OF MT. PELÉE
FORMED DURING THE GREAT ERUPTION OF MT. PELÉE ON THE ISLAND OF MARTINIQUE IN 1902, AND PHOTOGRAPHED BY THE LATE E. O. HOVEY, OF THE AMERICAN MUSEUM. THE SPINE RESEMBLES THE ONE SHOWN IN MR. BUTLER'S PAINTING OF A LUNAR LANDSCAPE.

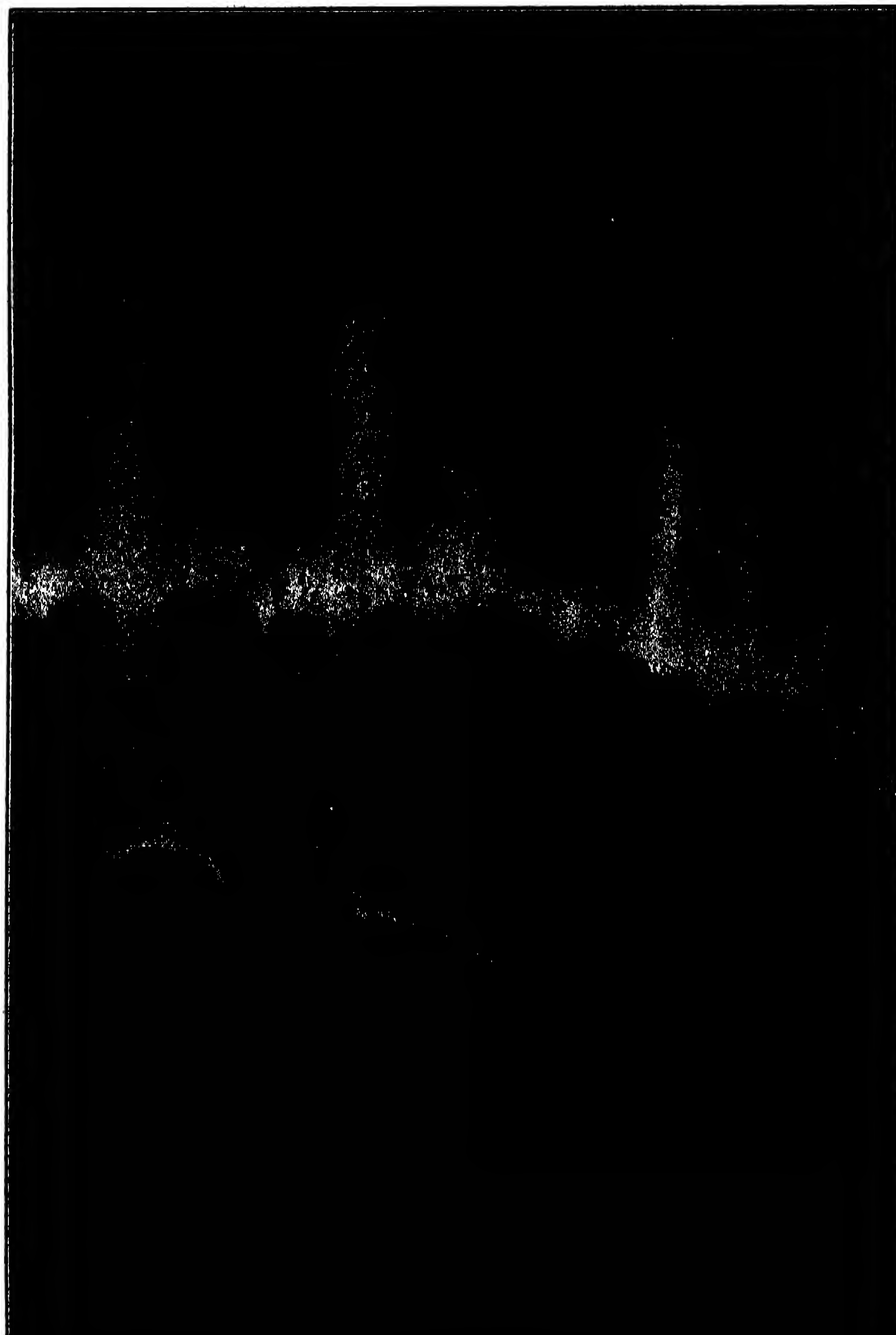
the cause of knowledge is advanced accordingly. It is largely through this exchange service that the Smithsonian Institution is known in every corner of the world where scientists foregather.

During the course of a year there pass through the Smithsonian Exchange Service a total of nearly 500,000 packages, which contain considerably more than 1,000,000 publications.

AROUND THE WORLD IN TWENTY-FOUR HOURS

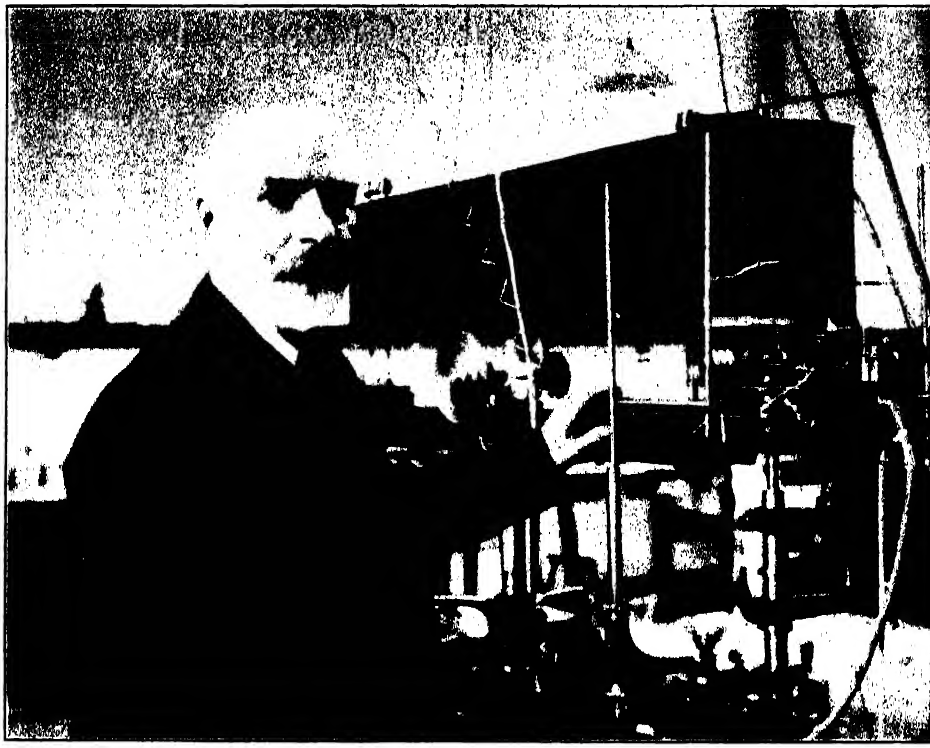
SEVERAL correspondents have written concerning the article by Dr. Charles H. T. Townsend, printed in the last month's issue of THE SCIENTIFIC MONTHLY. Mr. H. V. Haight writes from Sherbrooke, Quebec.

The article in your April issue "Around the World in a Daylight Day" by Dr. Townsend was most interesting and has tempted me to some further speculations as to more immediate possibilities. Dr. Townsend ignores the effect of the revolution of the earth. He assumes that the aviator starts at dawn, 4 A. M. of a summer day, and flies west at a rate to encircle the earth in 17 hours, returning to New York at dusk, 9 P. M., the same day.



AURORA BOREALIS

As seen from Ogunquit, Maine, on August 12, 1919. Photographed from a painting by Howard Russell Butler, N. A.



ARTHUR ROBERTSON CUSHNY

PROFESSOR OF THE MATERIA MEDICA AND PHARMACOLOGY IN EDINBURGH UNIVERSITY, WHO DIED ON FEBRUARY 25, AGED SIXTY YEARS. DR. CUSHNY WAS PROFESSOR AT THE UNIVERSITY OF MICHIGAN FROM 1893 TO 1905. THE PHOTOGRAPH WAS TAKEN IN DR. CUSHNY'S LABORATORY AT EDINBURGH, BY PROFESSOR W. R. MILES, OF STANFORD UNIVERSITY.

It will be apparent that, flying faster than the advancing daylight, what would happen would be that the aeroplane would fly back into the night, would encircle the earth in darkness and just emerge into daylight again on its return to New York at 9 P. M. Except for a short twilight at starting and on returning, the aviator would experience 31 hours of continuous darkness (7 hours the night before, 17 hours while flying, 7 hours the next night).

If this supposed aeroplane were flown a little slower, to encircle the earth in 24 hours, and started at dawn, the whole trip would be made at dawn, following the morning around the world. It would appear that Kipling must have had some such aeroplane in mind when he wrote:

> You may catch hold of the wings of the morning
> And flop round the world till you're dead,
> But you can't get away from the tune that they play
> And the blooming old rag overhead.

The aeroplane might go slower still, to get back at 9 P. M. and still make the circuit in daylight. That would give 41 hours of daylight. It is interesting to speculate on the possibility of making the circuit on the 50th parallel, where the distance is some 3,500 miles shorter

than on the 40th parallel, and yet where the country is nearly all inhabited. According to the Encyclopedia Americana, the length of a degree of longitude at the 50th parallel of latitude is 44.35 English miles, which makes the distance around the earth 15,966 miles. To fly around in 41 hours would require an average speed of practically 390 miles per hour, or a little over 50 per cent. above the present maximum speed of an aeroplane.

A fuel which presents possibilities for this service is heavy oil. Already the United States Government is testing an experimental 100 horse power oil engine for aeroplane service. The oil consumption of solid injection oil engines as used in the oil-electric locomotive is about .45 pounds per horse power hour, and it is to be hoped that the fuel consumption of an aeroplane engine can be brought down to ½ lb. per horse power hour.

If improvements in the aeroplane would make it possible to fly a machine at 400 miles per hour with a 500 horse power oil engine, the fuel consumption would be 250 pounds per hour, or 10,000 pounds for the 40 hours required to encircle the earth on the 50th parallel. The distance across the Atlantic, from Cornwall to Newfoundland, is only about 2,000 miles, and such an aeroplane would cross in 5 hours, with 1,250 pounds of fuel.

If a fly can go 800 miles an hour without replenishing its fuel supply at all, it does not appear unreasonable that an aeroplane should go 400 miles an hour with a fuel supply that would be adequate for a 500 horse power locomotive.

THE SCIENTIFIC MONTHLY

JUNE, 1926

THE STORY OF YALE'S GREAT MUSEUM

By ROLLIN LYNDE HARTT

An embarrassed young man, booked as Benjamin Silliman, Esq., boarded the stagecoach at New Haven one day in the winter of 1801–2. He was doubly embarrassed. Not only had Yale made him its professor of chemistry and natural history, sciences in which he could not yet claim proficiency, but he carried with him an exceedingly awkward candle-box, whose aspect aroused the curiosity of his fellow-travelers.

The candle-box contained Yale's entire mineralogical collection—and young Professor Silliman was on his way to Philadelphia, where dwelt Dr. Adam Seybert, then the sole American capable of telling authoritatively what the specimens were.

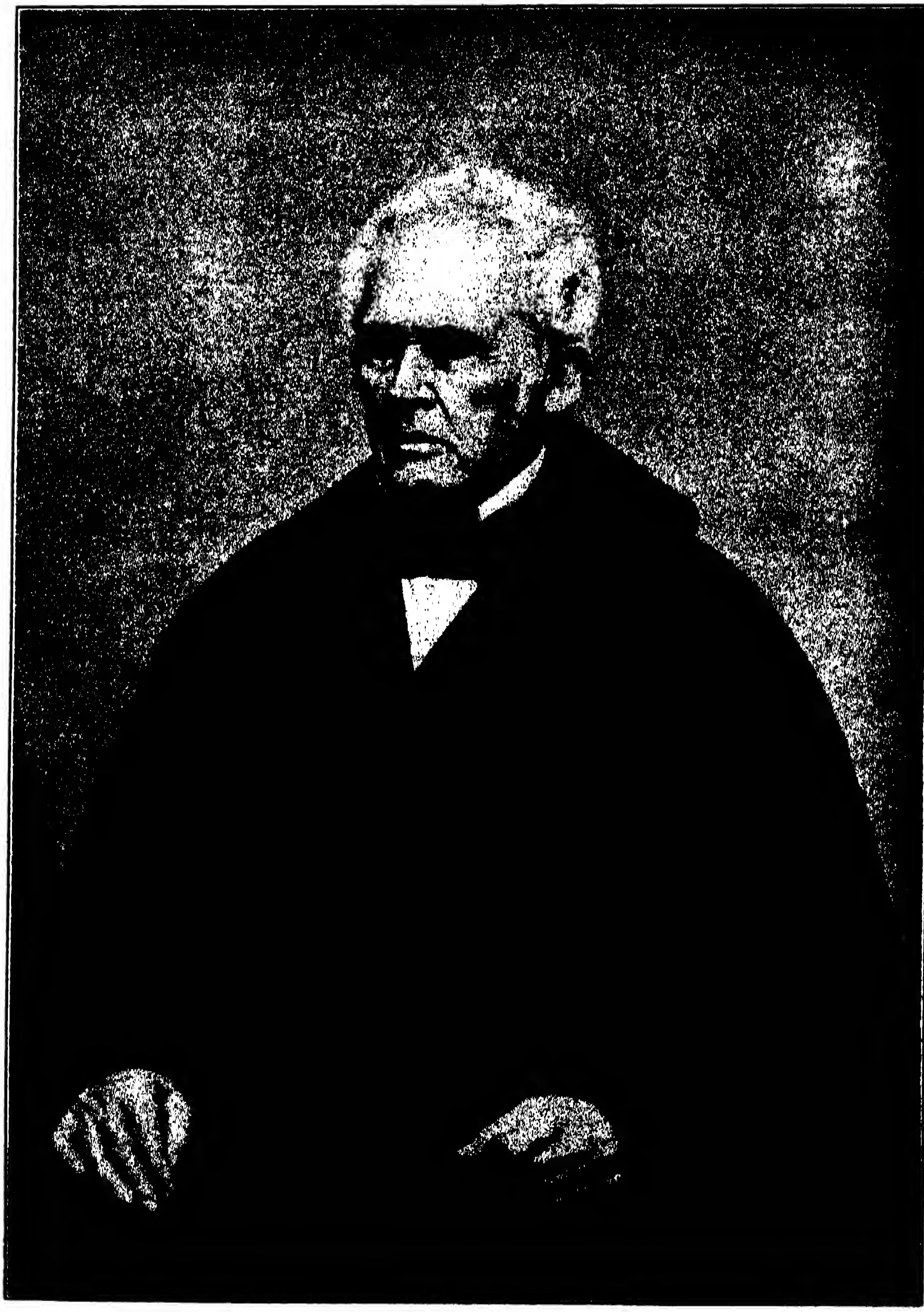
The visit to Seybert appears to have been fruitful, for Silliman returned to New Haven with Yale's possessions nicely ticketed and assumed his professorial duties fairly confidently. Not long thereafter, his brother presented the college with a few minerals brought from England. Then Silliman himself went abroad and fetched home a few more.

Such were the beginnings of what are now the famous collections of the Peabody Museum of Natural History at Yale—humble beginnings, but beginnings very encouraging to Silliman, who wrote, "All these things, when arranged and labelled, served to awaken an interest in the subject of mineralogy, and produced both aspirations and hopes, looking towards a collection which should by and by deserve the name of a cabinet."

Though a thousand dollars represented a serious sum in those days, Yale backed up Silliman in 1807 by expending that amount in acquiring the Perkins collection of minerals, and the professor installed it in his den. "Soon the news of the arrival of this cabinet was spread abroad," he wrote, "and my chamber was visited by many persons, ladies and gentlemen. Some were intelligent, and appreciated the cabinet in relation to science, and all were curious to see beautiful things."

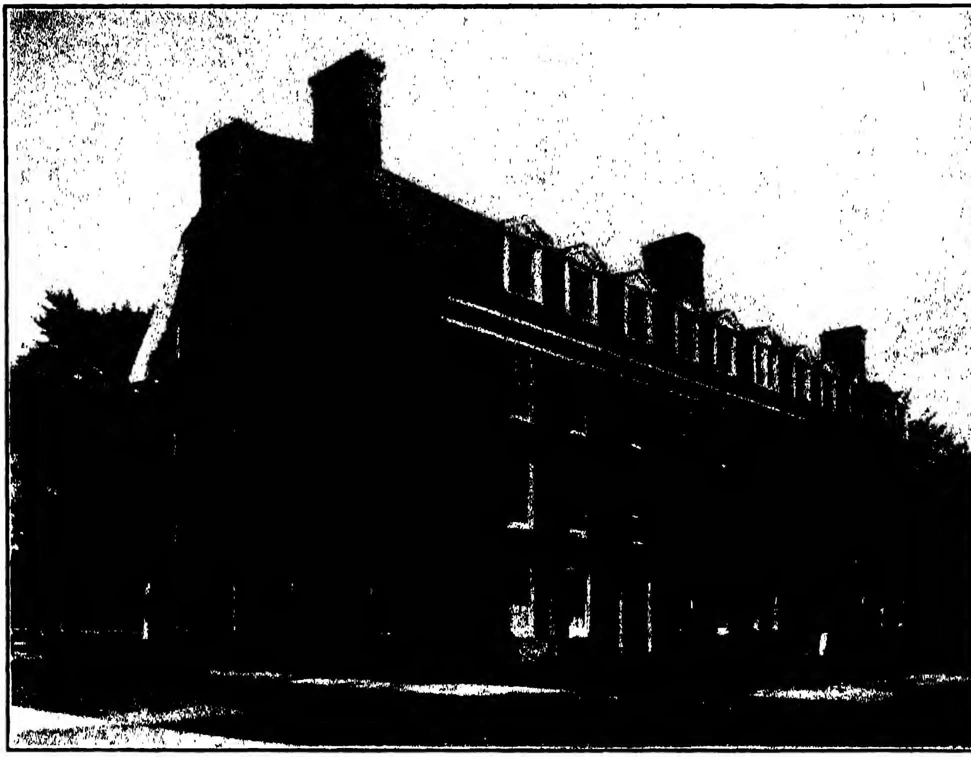
An indiscriminate welcome awaited them, one learns, and most unorthodox it was. In London, not many years before, the Dodsleys had published a guide to "The General Contents of the British Museum" and its author remarked:

> Some of my readers may be ignorant of the Manner of applying to see the Museum; for their Information I shall add, that fifteen Persons are allowed to view it in one Company; the Time allotted is Two Hours; and when any Number not exceeding fifteen are inclined to see it, they must send a list of their Christian and Sir-names, Additions, and Places of Abode, to the Porter's Lodge, in order to their being entered in the Book; in a few days the respective Tickete will be made out, specifying the Day and Hour in which they are to come, which on being sent for, are delivered. If by any Accident some of the Parties are prevented from coming, it is proper they send their Tickets back to the Lodge, as no body can be admitted



BENJAMIN SILLIMAN, SR.

PROFESSOR OF CHEMISTRY AND NATURAL HISTORY AT YALE FROM 1805 TO 1855



SOUTH MIDDLE, NOW CONNECTICUT HALL

IN TWO ROOMS IN THE SECOND STORY THE GIBBS CABINET WAS INSTALLED IN 1807 BY PROFESSOR SILLIMAN.

with it but themselves. It is to be remarked that the fewer Names there are in a List, the sooner they are likely to be admitted to see it.

Yale's first really important acquisition fell literally from the skies. A huge meteor, said by eye-witnesses to have been two thirds as large as the full moon, exploded over the town of Weston, Connecticut, with a noise like that of a great cannon, and showered the earth with fragments. Taking along Professor Kingsley, Silliman rushed to Weston, which is only twenty-five miles from New Haven, and spent several days picking up the pieces, one of which weighed thirty-six pounds.

This was in 1807, a few months after the acquisition of the Perkins cabinet. Three years later came an event still more thrilling. Colonel Gibbs, of Newport, R. I., had brought over a collection of minerals from England and now offered to loan it to Yale. On behalf of the college, President Dwight accepted, and in 1812 the Gibbs Cabinet was installed in two rooms let together in the second story of South Middle, now known as Connecticut Hall. At last, a museum! Forty feet, one way! Eighteen the other! Popular excitement ran high.

Long afterward Professor E. S. Dana wrote:

It is, perhaps, not easy for us, at the present time, to appreciate the profound impression which the collection made upon the visitors who came from far and near to see it. It was a time when scientific collections were few, and when specimens from Europe were rarely seen.

BENJAMIN SILLIMAN, JR.
TEACHER AND PROFESSOR OF CHEMISTRY AT YALE FROM 1837 TO 1885

In Silliman's own account of the Gibbs Cabinet, we read:

> It presented a rich and beautiful sight. The fame of this cabinet was now blazoned through the land. . . . It kindled the enthusiasm of the students, and excited the admiration of intelligent strangers. . . . It was visited by many travellers, and New Haven was then a focus of travel between north and south. Railroads were unknown, and navigation by steam had hardly begun. The comparatively slow-moving coaches conveyed the passengers, who were generally willing to pass a little time in New Haven; and the cabinet of Colonel Gibbs afforded a powerful attraction, while it afforded also a high gratification. . . . Trains of ladies graced this hall of science; and thus mute and animate nature acted in unison in making the cabinet a delightful resort.

For eight years this had continued, when in 1820 the cabinet was removed to the upper story of the then new building called the cabinet. There it seems still to have been a reigning attraction, for Colonel Gibbs's offer to sell it to Yale caused the wildest excitement five years later. Twenty thousand dollars was the price—a staggering sum!

Yale rose to the occasion magnificently, and began what was perhaps the first "drive" ever organized. With mass meetings, with pulpit appeals, and with a house-to-house canvass, New Haven "went over the top," and the renowned Gibbs Cabinet was purchased.

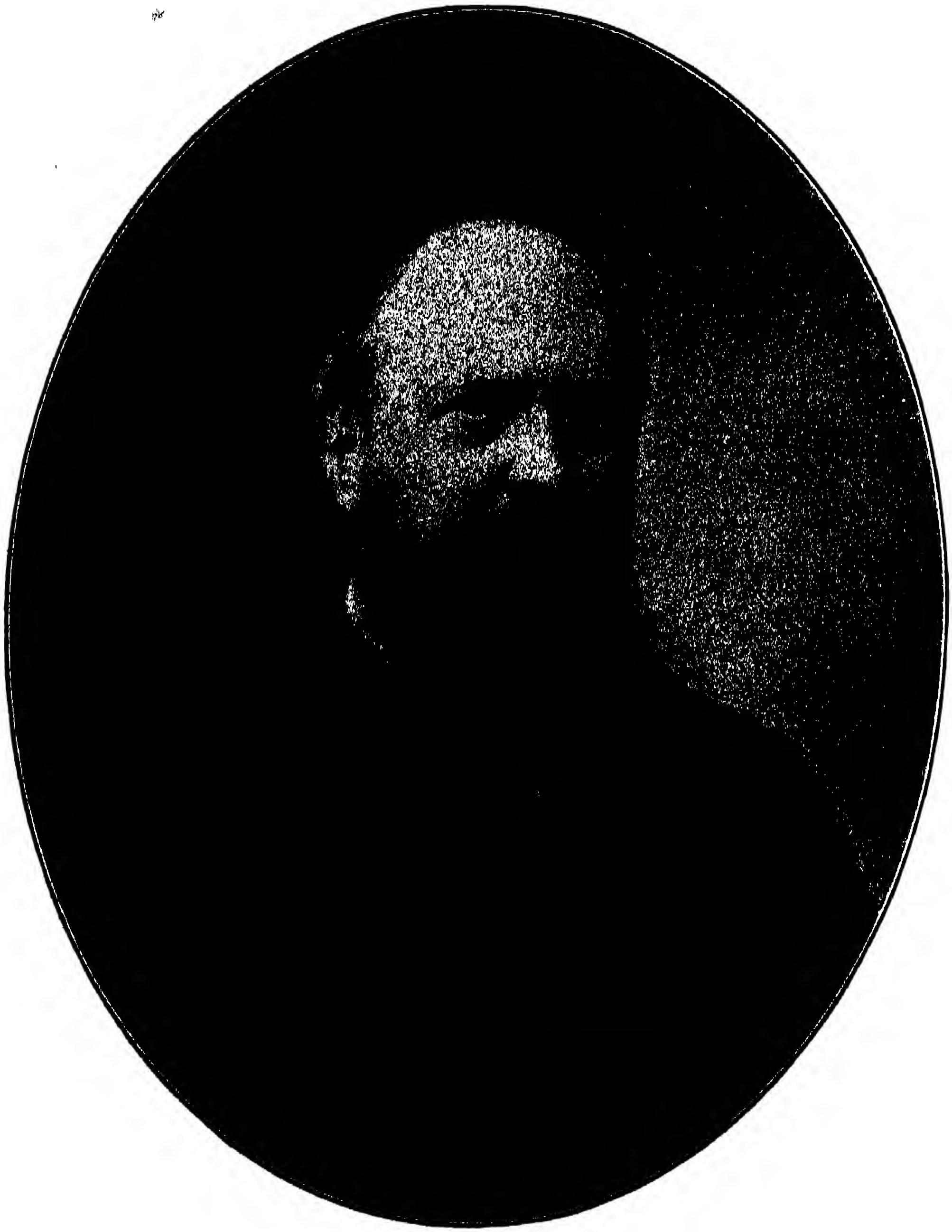
Then for a long time—more than sixty years, in fact—the museum pegged along rather uneventfully, enlarging its collections but experiencing few thrills of the first order. It was dur-

JAMES D. DANA
PROFESSOR OF GEOLOGY AT YALE FROM 1850 TO 1893

ing this period that the Baron Lederer collection was bought for $3,000, and numerous specimens added by Silliman and the elder Dana. Only one highly dramatic event occurred—the snatching of the Gibbs meteorite from the very verge of the grave and its presentation to Yale. In his account of the affair, Professor E. S. Dana tells us:

This great mass of meteoric iron weighs about three-fourths of a ton (1,635 pounds) and ranks as one of the three or four largest masses ever placed in a scientific museum. It was brought in 1810 to New Orleans from the Red River region in Texas, the belief being that it was a mass of platinum. From New Orleans it was shipped to New York; but the extravagant expectations as to its commercial value were not realized, and it was finally bought by Colonel Gibbs for $500. He presented it, in trust, to the museum of the Lyceum of Natural History in New York. On the removal of the Lyceum from the Park, it was left at the doorway, apparently forgotten. Mrs. Gibbs, the widow of Colonel Gibbs, happening to pass the spot one day, saw some workmen in the act of burying the iron in a hole they had dug for the purpose "to put it out of the way." She rescued it from its threatened burial, and sent it to New Haven, presenting it to the College in memory of her husband.

It was not until 1866 that the growing museum caught the attention of an "angel" and came into a fortune, the gift of George Peabody, an expatriated



OTHNIEL CHARLES MARSH

PROFESSOR OF PALEONTOLOGY, THROUGH WHOSE EXPLORATIONS THE GREAT COLLECTIONS OF VERTEBRATE FOSSILS OF THE PEABODY MUSEUM WERE OBTAINED. MARSH WAS A NEPHEW OF GEORGE PEABODY.

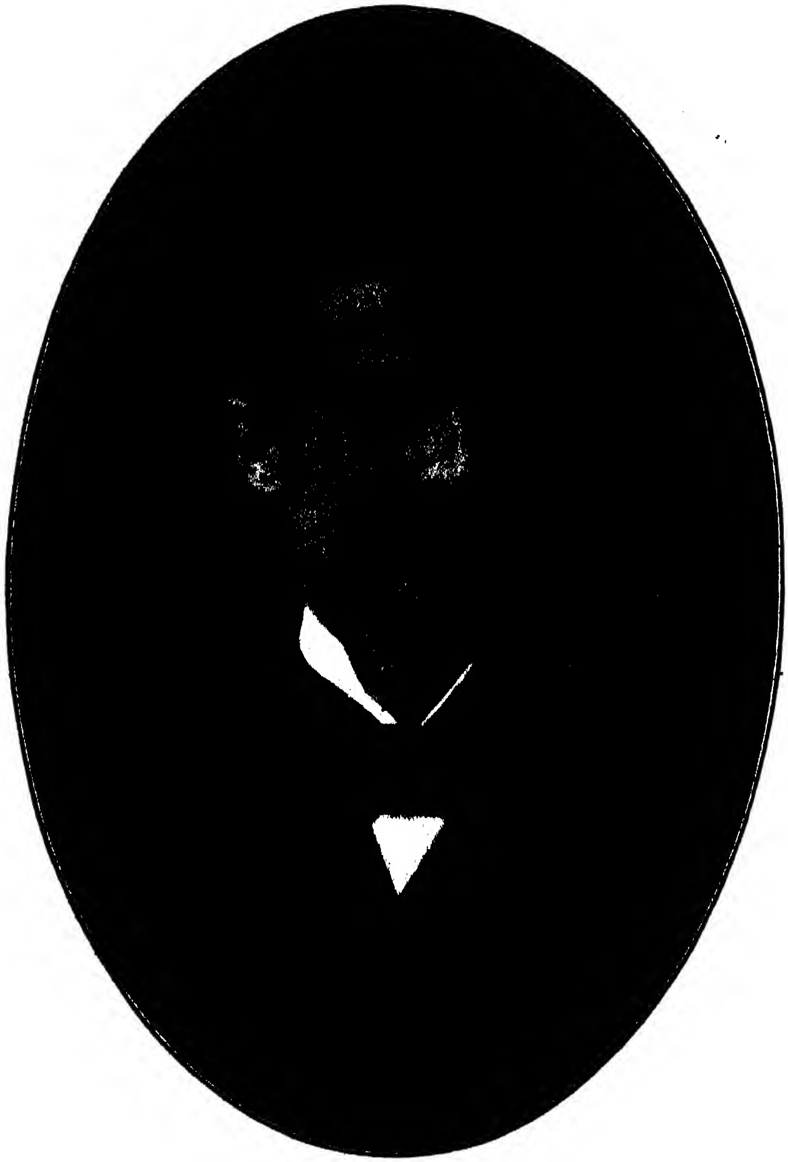
THE FIRST PEABODY MUSEUM

ERECTED IN 1874 AND TORN DOWN SEVEN YEARS AGO TO MAKE ROOM FOR THE MEMORIAL QUADRANGLE.

American who had become a merchant, banker and celebrated philanthropist in London. An old number of the *Critic*, issued just after the Peabody centenary in 1895, contains a sketch of his career as a giver. All told, his varied benefactions amounted to about $12,000,000, and the writer, while confessing that to obtain a complete list of them would be impossible, informs us:

In 1852 he contributed to the fitting up of Dr. Kane's Arctic Expedition and founded the Peabody Institute, endowing it subsequently with $200,000. To the Baltimore Institute of Science, Literature and Art he gave $1,000,000; in 1862, he established a fund of $2,000,000 for the building of lodging-houses for the London poor. This fund has been increased by judicious management to $5,470,000. In 1866 he gave $150,000 to Harvard for its Peabody Museum and Professorship, and an equal sum to Yale for a department of physical science. He established a Southern educational fund of $2,100,000 for the erection of common schools; founded the Peabody Academy of Science at Salem, Mass., in 1867, endowing it with $140,000, and presented $60,000 to Washington College, Va.; $50,000 to the Peabody Institute of North Danvers; $30,000 to Phillips Academy, Andover; $25,000 to Kenyon College, Gambier, Ohio, and $20,000 to the Maryland Historical Society. He endowed, also, an art-school in Rome.

Although it may be considered a great liberty to criticize the *Critic*, "a department of physical science" was certainly a most inadequate designation of what Peabody brought into being at Yale. What he actually brought into being was the Peabody Museum of Natural History at Elm and High Streets. One wing of the museum was erected in 1874, and the *Yale Courant* observed: "The building, when completed, will not only be the largest but also the most imposing and important in the city. It is to be for the use of all departments of



EDWARD WARD BEECHER
PROFESSOR OF INVERTEBRATE PALEONTOLOGY UNTIL HIS DEATH IN 1904.

the university alike, and will be, like the Art School, a fountain of instruction and entertainment to the public of New Haven. The generous donor has by this gift written his name indelibly upon the memories and hearts of all connected with Yale College, and has done a noble work for natural science.'' The building was never completed. Mr. Peabody died three years after his gift to Yale and never saw even the one wing.

As the museum found in Peabody its angel, so in Othniel Charles Marsh, Peabody's nephew, it found its most celebrated champion and servitor. Marsh, who had been the first to interest Pea-

body in the scientific movement at Yale, was born in Lockport, N. Y., and the Yale necrologist tells us:

His early advantages were limited, but in 1857 his uncle offered him a higher education and he began his preparation at Phillips Academy, Andover, Mass. Before he entered Yale his scientific bent was already manifest, and he had even begun in a modest way his career as an explorer and discoverer. For two years after graduation he pursued the study of natural science in New Haven, and then spent several years in close study in Germany. In the meantime he had contributed several papers to the *American Journal of Science*, and as early as 1863 his ability had been recognized by his election as a Fellow of the Geological Society of London. On his return from London, he was elected Professor of Paleontology at Yale. Professor Marsh was appointed Curator of the Geological Collections of the College in 1867, and under his superintendence the first wing of the Museum was completed.

A born explorer, Marsh saw in his new position an incentive not only to enrich the museum with new acquisitions but to enrich science itself with new discoveries. Writing of him in Kingsley's "Yale College," George Bird Grinnell says:

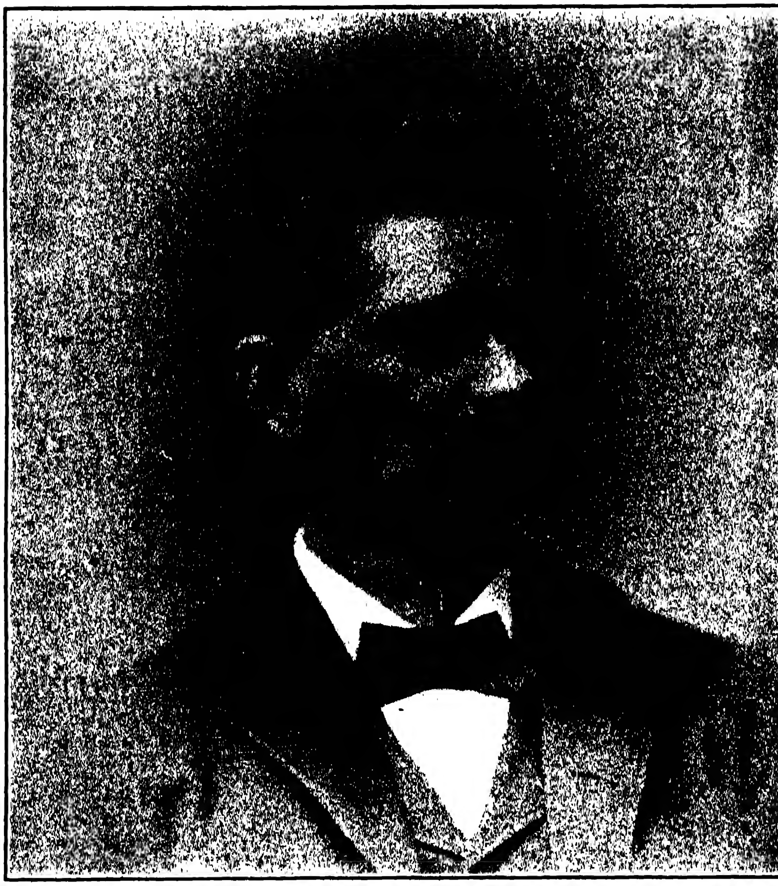
After having spent several years in bringing together, from the Cretaceous and Tertiary of the Atlantic coast, a very considerable mass of material, he came to the conclusion that this field was essentially exhausted, and that it was to the West, to the unexplored territory beyond the Missouri River, that the paleontologist must look for the facts which would lead him to an intelligent comprehension of the progress of vertebrate life in the past. This conclusion was confirmed by his own observations made during a short trip to the Rocky Mountains in 1868, during which he obtained much information, which proved of the greatest value in his subsequent visits.

Accordingly, in 1870, the first of the Yale Scientific Expeditions was organized, and, after spending five months in the field, returned well laden with fossil treasures from the Cretaceous and Tertiary formations. The success of this experiment was so marked that the four succeeding years witnessed the departure of as many expeditions, all of which were successful, and the results may be briefly summed up in the statement that, altogether, within six years from the time that the first one started out, these expeditions under Professor Marsh had brought to light no less than four hundred species of vertebrate fossils new to science. At the time these explorations began, the far West was almost wholly unknown, and the investigators were exposed to great hardships, and to no little danger from hostile Indians.

Professor Richard S. Lull, the museum's present director, relates that "one day with the thermometer at from 110 to 115 the party marched for fourteen hours without water. Another such day would have destroyed half the stock and produced the saddest results among the men." Also, he tells us that though the explorers had a military escort, and were accompanied by Buffalo Bill, "the redskins set the prairie on fire when the party were encamped, and only by the utmost exertion did the latter save themselves and their animals from the flames." One winter they had an Indian escort wished on them under the leadership of Sitting Bull, and Professor Lull tells us:

This escort was ostensibly to guard the party against the Northern Indians, but really to keep watch upon the actions of the bone-hunters. The next day snow fell, delaying the departure. In the meanwhile the annuities were issued, so the Indians were no longer on their good behavior. So hostile a demonstration was made that their departure would probably have precipitated a general mêlée, and the only prudent thing to do was to withdraw. Later another escort was furnished by the Indians.

When the test came, however, the Indians again refused to go. Finally, exasperated by the numerous delays, Professor Marsh decided to evade the Indians, and shortly after midnight the expedition filed as silently as possible between the Indian villages to the only place where the White River could be forded. As they marched by, the Indian dogs barked furiously, but their owners slept. By daylight Indian scouts were riding from village to village giving the alarm, and horsemen were seen posted on the high buttes to watch the party. After a rapid march a strong camp was pitched and the exploration and collecting was carried on in the intense cold as rapidly as possible. Threats of attack by the Northern Indians made the risk of remaining very great, but in spite of it



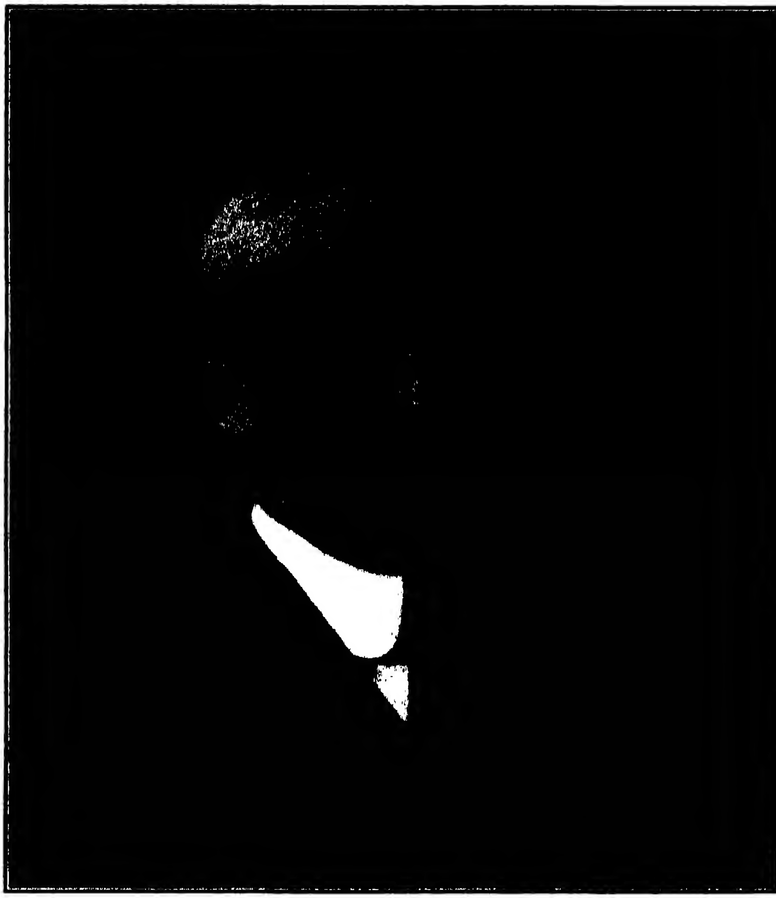
PROFESSOR A. E. VERRILL

PROFESSOR OF ZOOLOGY AND CURATOR OF THE ZOOLOGICAL COLLECTIONS FROM 1864 UNTIL HIS RETIREMENT IN 1907.

sufficient time had to be taken to pack the fossils, which would otherwise have been destroyed in transit. The party retreated, however, none too soon, as a large war party scoured the Bad Lands the next day in a search for the intrepid white "Bone Chief" and his band.

Among the fossils which Marsh brought home from the west were those of toothed birds, very important as illustrating evolution; of the horse and its precursors; of the first pterodactyl ever found in America and the first apes; of giant turtles and giant sloths; of marsupials and bats never before known to have existed here; of birds, serpents, lizards and fish; of the prehistoric rhinoceros; and of amazing dinosaurs. In his letter presenting his collections to Yale in 1898, he said of his vertebrate fossils:

This is the most important and valuable of all, as it is very extensive, contains a very large number of type specimens, many of them unique, and is widely known from the descriptions already published. In extinct mammals, birds and reptiles, of North America, this series stands preeminent. This collection was pronounced by Huxley, who examined it with care in 1876, to be surpassed by no other in the world. Darwin, in 1878, expressed a strong desire to visit America for the sole purpose of seeing this collection. Since then it has been more than doubled in size and value and still holds



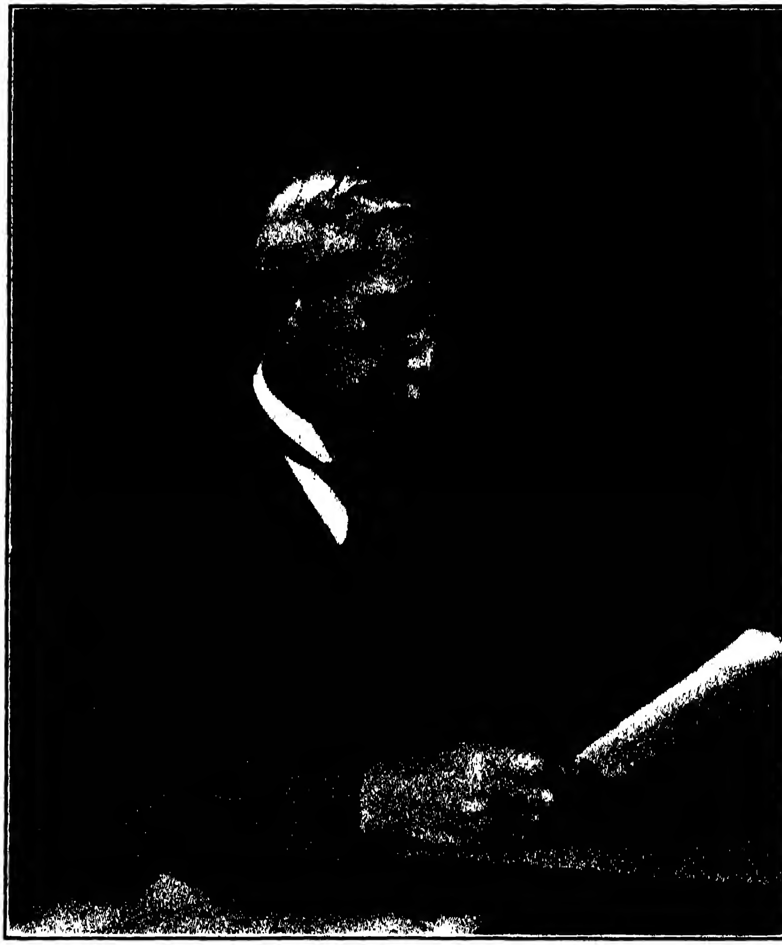
PROFESSOR EDWARD S. DANA

PROFESSOR OF PHYSICS AND CURATOR OF THE MINERALOGICAL COLLECTIONS FROM 1874 UNTIL HIS RETIREMENT TO BECOME PROFESSOR EMERITUS IN 1918; TRUSTEE OF THE PEABODY MUSEUM SINCE 1885; EDITOR OF AMERICAN JOURNAL OF SCIENCE SINCE 1875.

first rank. The bulk of this collection has been secured by my western explorations, which have extended over a period of nearly thirty years, during which I have crossed the Rocky Mountains twenty-seven times.

He might have added that for nearly thirty years he had served without salary and that he had spent upon his collections more than $250,000 of his own money.

Along with the vertebrate fossils went Marsh's great collection of fossil footprints, mainly from the Connecticut Valley and among the most extensive series in America; his invertebrate fossils, including the largest collection of nearly entire trilobites yet discovered and one of the rarest series of Silurian sponges known; his collection of recent osteology, especially rich in anthropoid apes, the gorillas being represented by no less than thirteen individuals; his archeological and ethnological specimens, mostly from Central America; and his minerals, of which the most interesting were the Nova Scotian zeolites collected before his graduation from Yale.



PROFESSOR CHARLES SCHUCHERT

PROFESSOR OF PALEONTOLOGY AND CURATOR OF THE GEOLOGICAL COLLECTIONS FROM 1904 TO 1923.

Another indefatigable collector for the museum was Professor Addison E. Verrill, long curator of zoology and still living. Of its marine fauna, he wrote in 1879:

This collection, which is one of the largest in the Museum, is almost wholly the result of the dredging expeditions made along our coast during the last fourteen years by the curator, aided by Professor Smith and others. He made private expeditions every vacation up to 1871, when the United States Commissioner of Fish and Fisheries was organized, with Professor S. F. Baird as commissioner. Since that time the curator has had charge of the dredgings carried on in connection with the commission, and the large collections of invertebrates have been sent to him for study and distribution, with the privilege of retaining here a complete series of them.

As the present curator of zoology, Professor Wesley R. Coe, tells us, "hundreds of thousands of specimens were thus added to the museum collections, among them being hundreds of previously unknown species. These vast collections, supplemented more recently from other parts of the world, have furnished material for research by successive members of the staff in the inter-

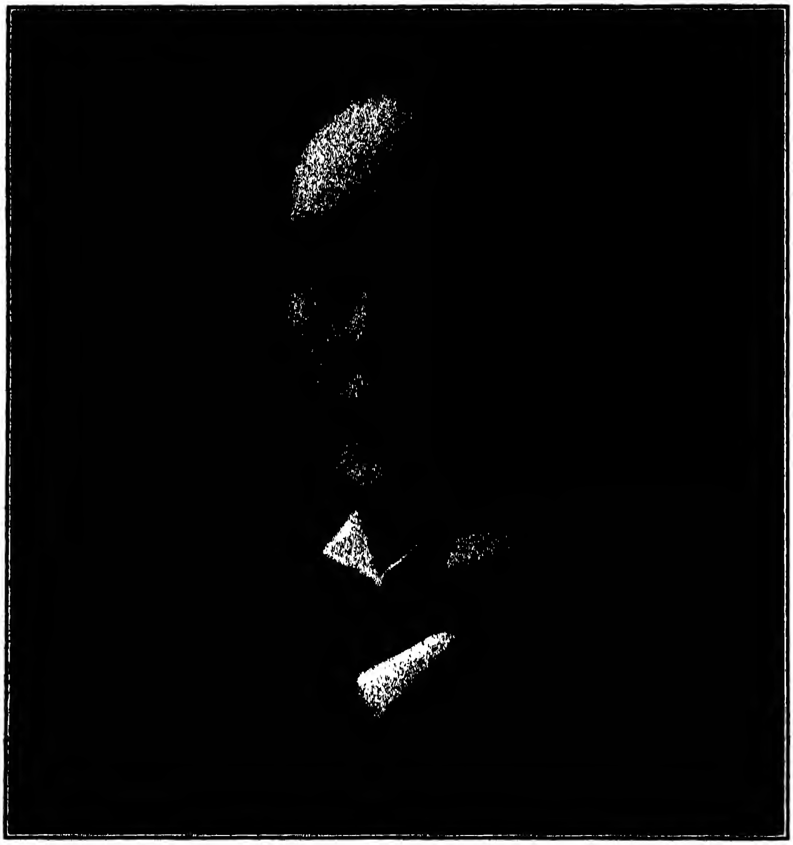
DR. CARL O. DUNBAR

ASSISTANT PROFESSOR OF HISTORICAL GEOLOGY ADD ASSISTANT CURATOR OF THE GEOLOGICAL COLLECTIONS SINCE 1920.

vening years, and even yet the work remains incomplete.''

In the nineties and during the early years of the present century the museum added enormously to its possessions. The mineralogical cabinet received the Williams collection of Chinese curios carved from jade, amethyst, rock crystal, etc., the Leonard collection and the Beadle collection, while the already extensive array of meteorites was increased by a collection of between nine hundred and a thousand stones got together by Mr. and Mrs. English after a meteoric shower in Iowa. The zoological department also prospered, adding the Hawley collection, the Eddy collection and the Perrin collection. The anthropological department added the MacCurdy collections and many others. The various Yale-Peruvian expeditions under Professor (now Senator) Hiram Bingham made still further contributions. Then, too, there were additions to the collection of vertebrate fossils, and Professor Lull explains:

The year 1908 saw the organization of the first formal expedition in search of fossil vertebrates since before the death of Professor Marsh in 1899. This party, consisting of the writer and Hugh Gibb, for more than thirty years a thoroughly efficient and skillful pre-



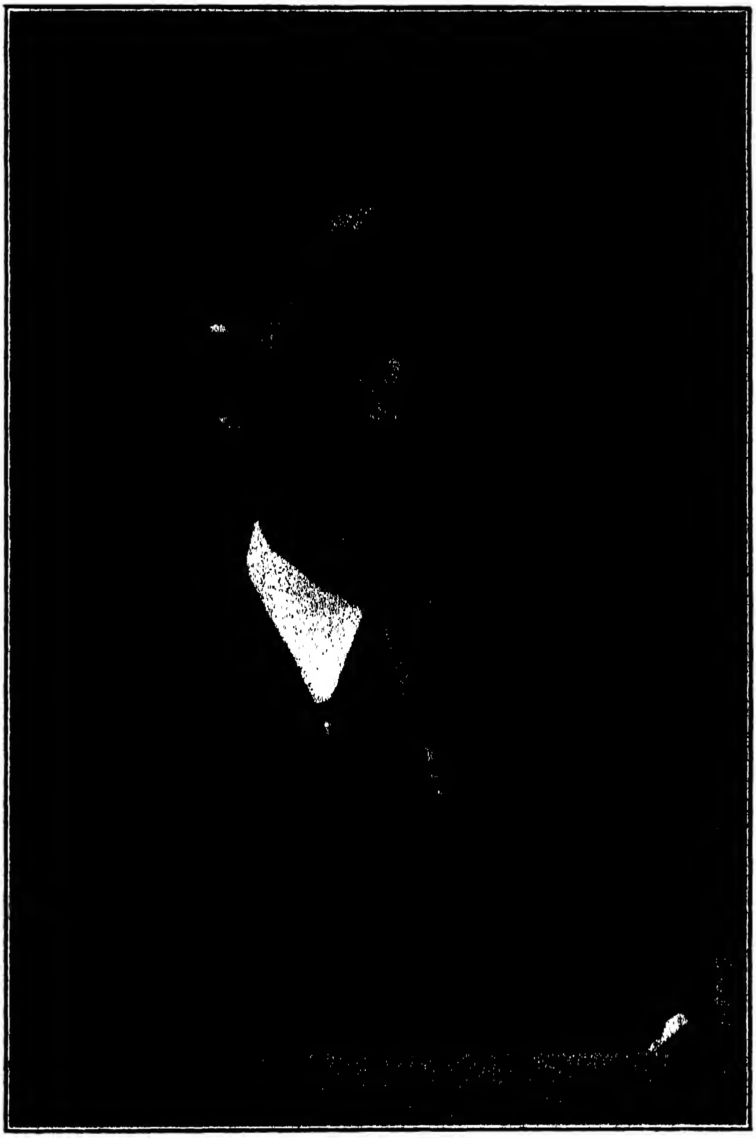
PROFESSOR GEORGE GRANT MACCURDY

RESEARCH ASSOCIATE WITH RANK OF PROFESSOR AND CURATOR OF THE ANTHROPOLOGICAL COLLECTIONS OF THE PEABODY MUSEUM SINCE 1923; DIRECTOR OF THE AMERICAN SCHOOL IN FRANCE FOR PREHISTORIC STUDIES.

parator in the Museum, joined forces with a larger party from Amherst under the leadership of Frederick B. Loomis, Professor of Comparative Anatomy in that institution. While the parties lived and traveled together, the collections were independently made. The work was done in beds of Lower Miocene age both in eastern Wyoming and along the historic Niobrara, though far to the west of the country exploited by the expedition of 1871. In spite of rich returns of camel, oreodont and other material, but few horses were secured, and those pertaining entirely to the genus *Parahippus*.

Fossil horses were then what most interested Professor Lull, and he continues:

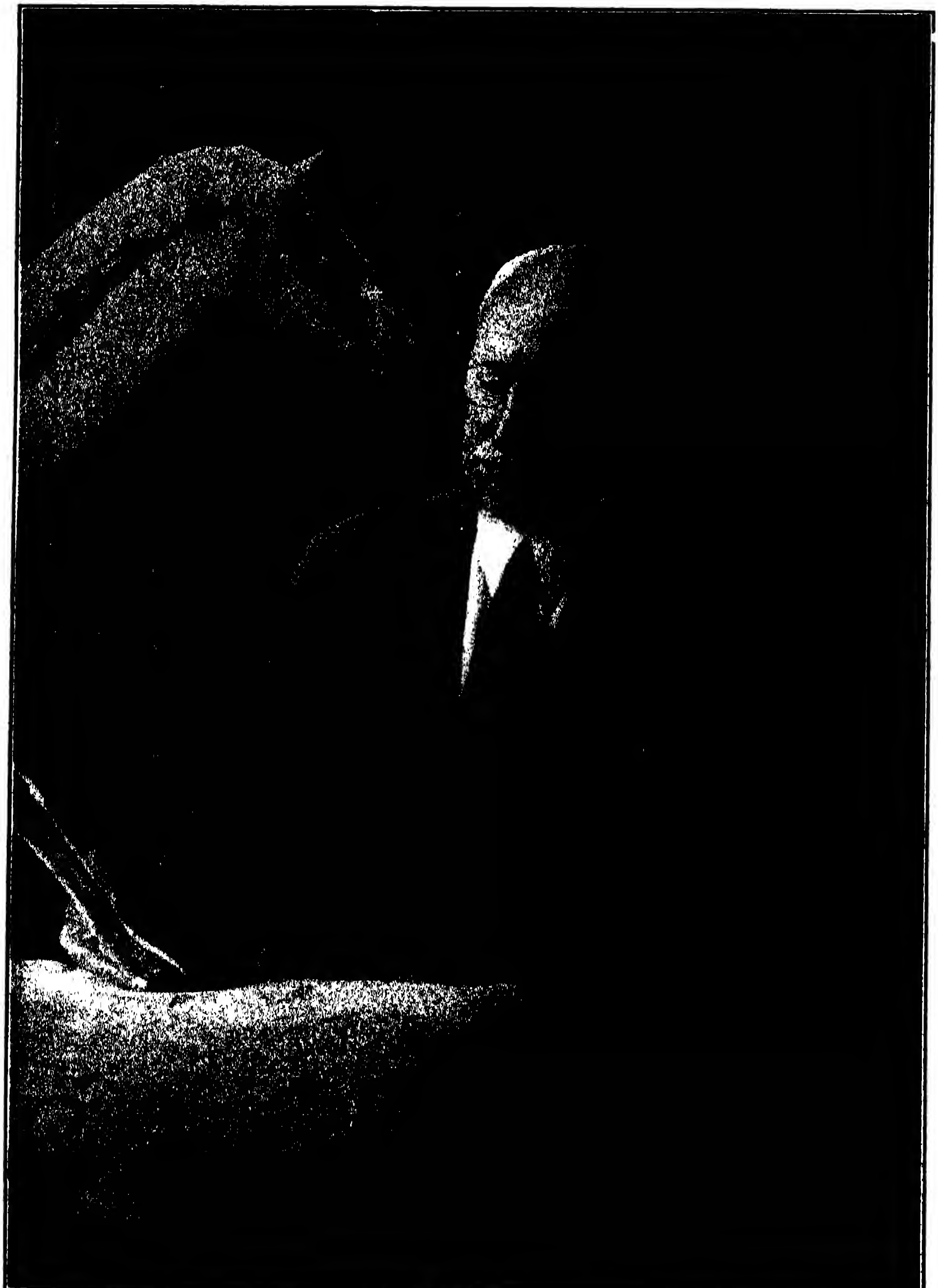
As a direct result of the 1908 expedition, it became possible during the summer of 1912 to send a larger party to the Panhandle region of Texas with the specific aim of securing one or more complete skeletons of fossil horses for the collection. The results so far as known are the obtaining of a practically perfect skeleton of *Equus scotti*, the last survivor of the horse family in North America, and several other incomplete skeletons; a partial skeleton and many teeth and bones of a smaller, more slender *Equus*; and from the Miocene (Clarendon) beds portions of many individuals of the three-toed *Protohippus* and *Pliohippus*, and the desert *Neohipparion*. The party was also successful in securing a great deal of material other than horses. Mrs. Lull collected several specimens of *Neohipparion* and *Protohippus*.



PROFESSOR WESLEY R. COE

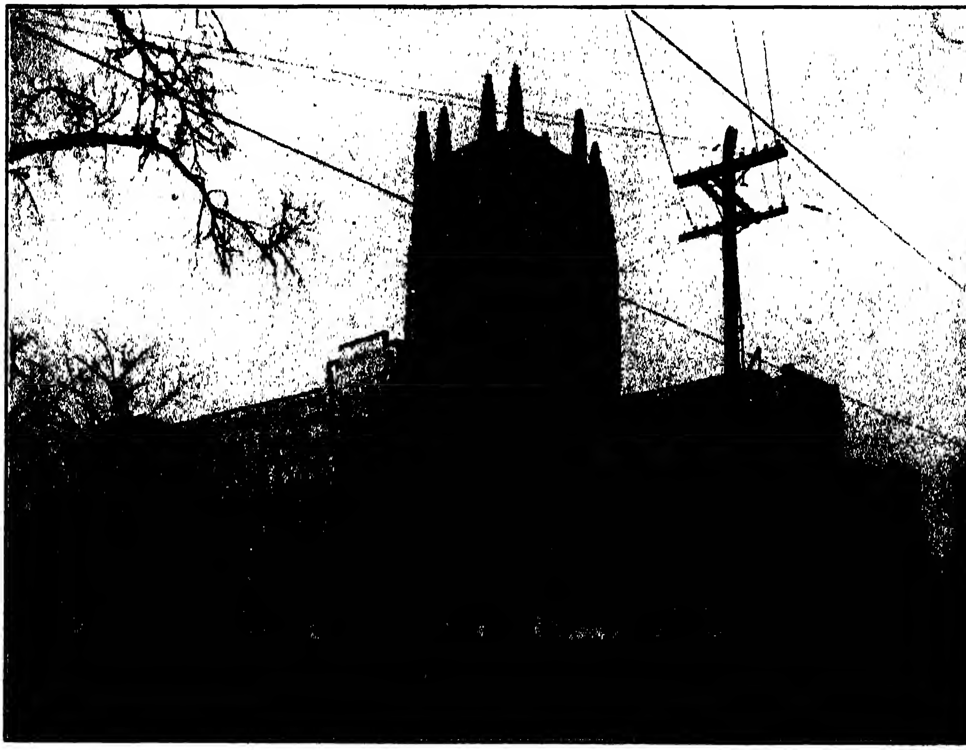
PROFESSOR OF BIOLOGY AND CURATOR OF ZOOLOGY SINCE 1909.

The Peabody Museum, long famous, became more and more a mecca for research specialists as its collections increased. Scientific men came from all over the world to study the exhibits, as they could find material there which could not be found elsewhere. A tremendous amount of scientific literature was based upon its collections, which in volume are second only to those of the Natural History Museum in New York and among the greatest in the world. It is impossible to pick up a single technical book along the lines of natural sci-



DIRECTOR RICHARD S. LULL

PROFESSOR OF PALEONTOLOGY SINCE 1906 AND FIRST DIRECTOR OF THE PEABODY MUSEUM.



THE PEABODY MUSEUM OF NATURAL HISTORY OF YALE UNIVERSITY
DEDICATED ON DECEMBER 29, 1925.

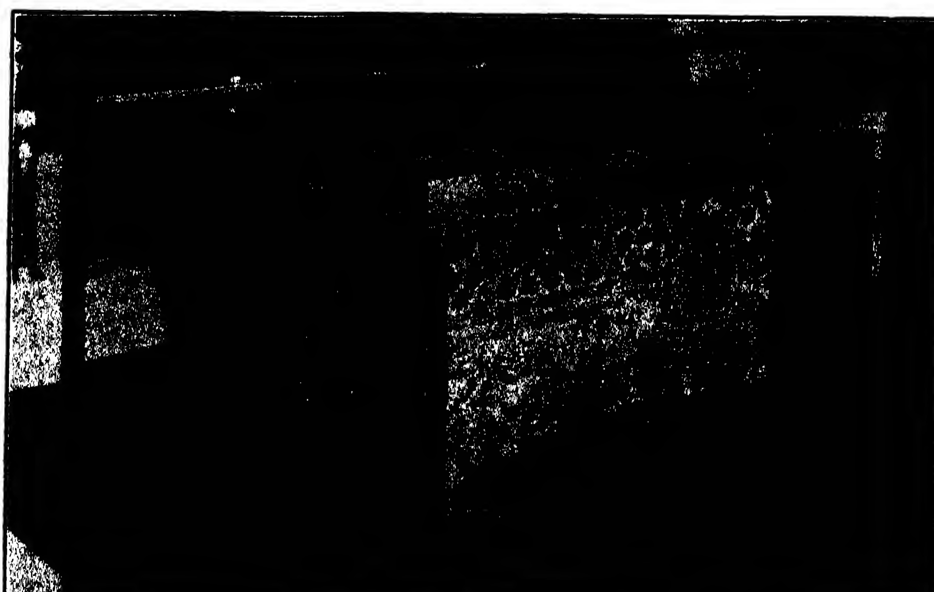
ence without finding some reference to the museum or to some member of its staff. Conspicuous among books written by members of the staff are Professor Schuchert's "Historical Geology," now used by two hundred colleges and universities, Professor Lull's "Organic Evolution," and Professor MacCurdy's "Human Origins."

Thirty years ago the need for expansion was felt, and the president reported that enlargement of the building "could no longer be delayed if the University and the public were to have the benefit of the unsurpassed collections which had been brought together with much labor and at great expense." Later on, the demand was repeated, becoming a chorus of demands, and chronic. The undergraduate press editorialized it. A contributor to the *Yale Alumni Weekly* versified it in the wail of a seventy-foot dinosaur crying out for room to stretch his bones. How the new building was at last promised is told in the address delivered by Professor Charles Schuchert at its dedication last December. Says Professor Schuchert:

On the memorable Christmas Eve of 1916, the treasurer of the University came to the speaker full of the great news of the Harkness gift of a magnificent new quadrangle of buildings, and asking our help to make it possible by the removal of the Peabody Museum from its stand of over forty years at the corner of Elm and High Streets. His words are still ringing in my ears, and I hear him say, "If you can bring this about, the present Peabody Museum building fund of $250,000 will be increased to $750,000, bearing interest at the usual university rate, along with more land than the Peabody Trustees now have on the Pierson-Sage

THE GREAT SABER-TOOTHED CAT

SHOWING THE METHOD USED BY PROFESSOR LULL, WHICH IS TO MOUNT A SKELETON AND THEN MODEL FLESH ON ONE SIDE OF IT, WORKING FROM THE COMPARATIVE ANATOMY OF DOMESTIC ANIMALS.



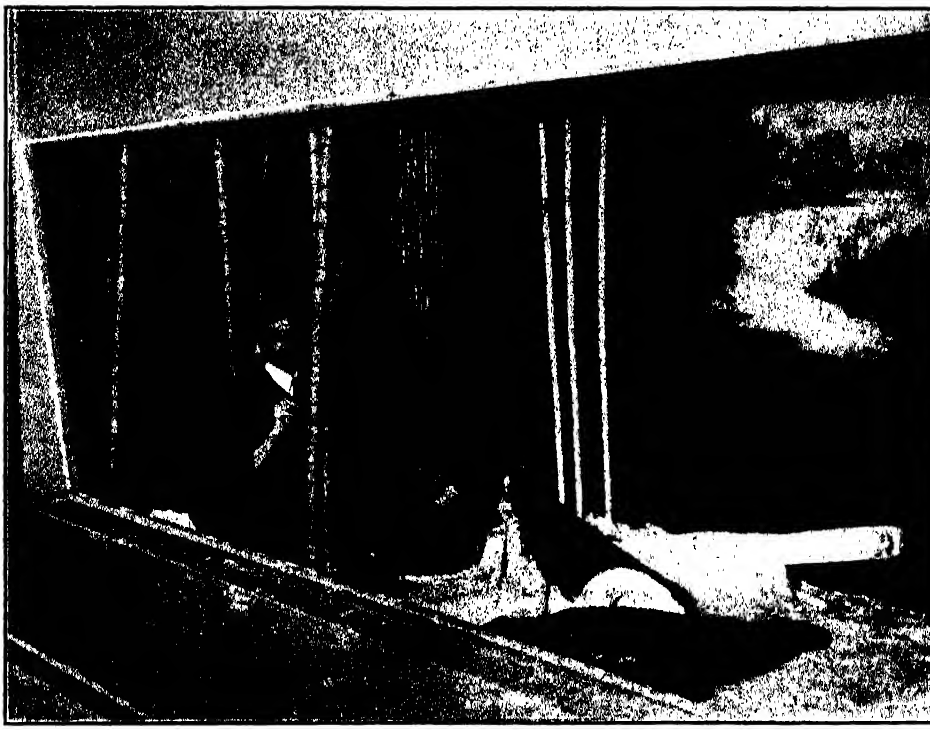
AZTEC CALENDAR STONE

ONE OF THE THREE EXTANT AND THE ONLY ONE OUTSIDE MEXICO. ON IT HUMAN SACRIFICES WERE OFFERED TWICE EACH YEAR TO THE SUN GOD.

Square.'' It was truly to be a grand Christmas present for the Museum, but, he added, ''The Museum must be erased and the property ready for the Memorial Quadrangle by July next!'' I said, ''Do you mean that we are to begin moving at once, go for two years into storage, and then move again into a new building?'' He nodded assent. I then asked him if he had not heard that ''three moves are as good as one fire.'' We laughed a ''good-night,'' but the consequence of that meeting was that the seemingly impossible conditions were fulfilled, and the wreckers began the demolition of the old Peabody Museum on the date appointed.

The expectation had been that we would have to wait but two years for a new building, and our material was accordingly stored in fifteen different places. Then President Wilson put us into the Great War, and before the memorable year of 1917 was at an end, the purchasing power of our funds had decreased to fifty cents on the dollar! Instead of two years, seven long years of gloom and confinement were our portion.

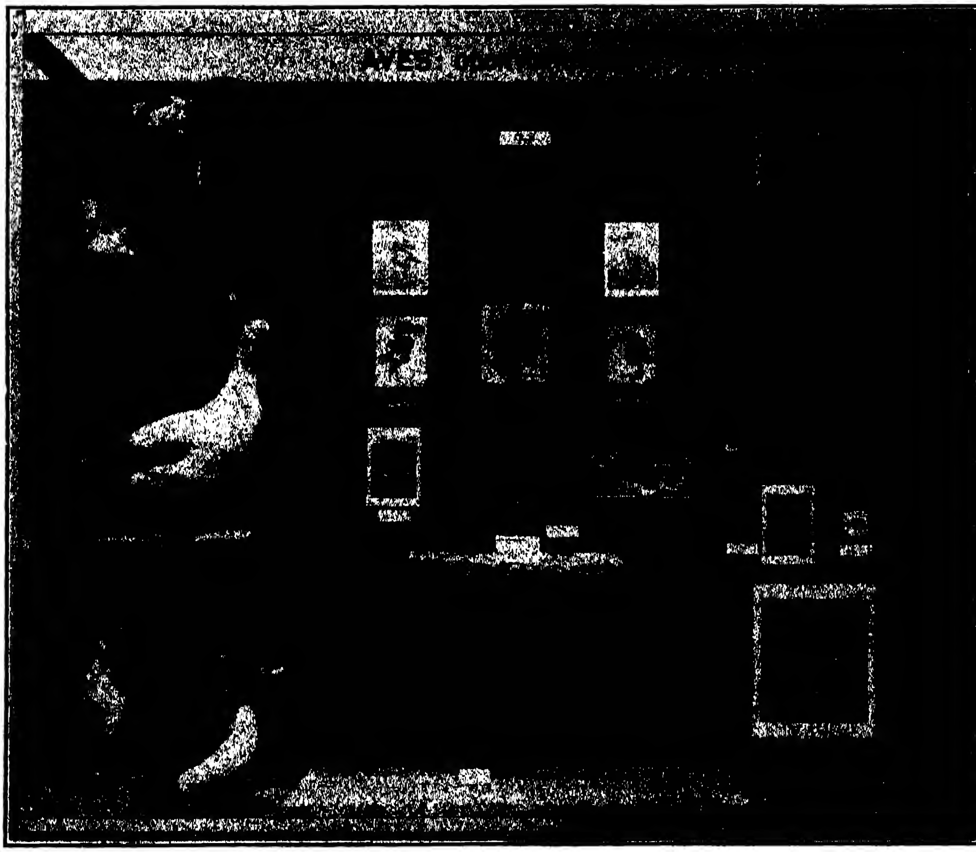
Moving out was a tremendous job. Provision for crating, carting and storage cost something like $23,000. Moving into the new building seven years later was a job almost as big. Over four hundred truckloads of material, largely the actual specimens, had to be hauled. Very little damage was done, other than that caused by deterioration during storage.



A CARBONIFEROUS LANDSCAPE

BRUCE HORSFALL, ASSISTANT EDITOR OF ''THE NATURE MAGAZINE'' AND PAINTER OF MANY HABITAT GROUPS FOR THE AMERICAN MUSEUM OF NATURAL HISTORY, IS SHOWN AT WORK UPON A REPRESENTATION OF THE PREHISTORIC COAL AGE.

The new building, which has been described not only in the SCIENTIFIC MONTHLY, but in the *Outlook*, *Museum Work*, the *Literary Digest* and numerous other publications, is a triumph of applied foresight. Cases were designed



ODONTORNITHES FROM THE CRETACEOUS

TWO RARE SKELETONS OF TOOTHED BIRDS FIRST DISCOVERED BY MARSH.

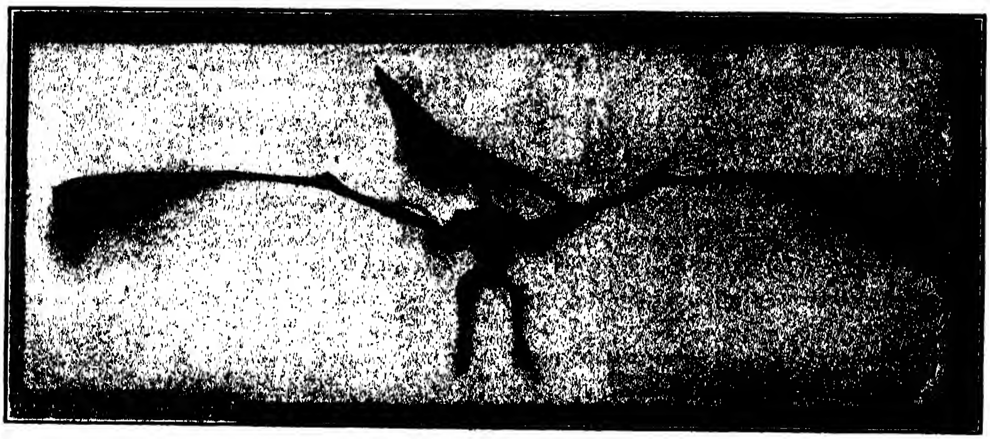
and in process of construction while the building was being erected. In October, 1924, they began to receive the specimens. By dedication day, December 29, 1925, all was ready. Costs had been so shrewdly calculated that there was a considerable sum left over from the building fund.

What, now, of the museum's future? "The museum must not stand still," says Professor Lull, "because whatever stands still goes backward. The museum could be larger; we already see that; for even the storage collections are pretty crowded, and some of that material, not yet scientifically described, has remained unopened ever since its arrival half a century ago. That is because Professor Marsh, who accumulated a vast deal of material for great monographs, seemed to believe more in immortality on earth than in immortality in another world, and died leaving only two of the great monographs completed. I have carried through a third. In course of time, more will follow, for these collections in storage are of tremendous importance. As one man has expressed it, the real scientific value of the museum lies in the basement."

Architecturally, the museum's enlargement will be a simple matter, as the Gothic permits irregularity and a new wing can be run out almost anywhere

without detriment to the design. One such addition is already planned—an auditorium. For this is primarily a teaching museum, serving the university departments.

But it is also a museum for the people of New Haven and their children. At present, it offers the children a museum within a museum. The next step will be to found a children's museum outside. Specimens are being set aside for that purpose, and intense is the interest among the children, though hardly less intense than the interest their parents have shown in the museum as now arranged. When the new building was first opened on Sunday, thirty-five hundred people came. On the third Sunday fifty-seven hundred and fifty-six came, and during the first eight weeks over forty-seven thousand.



SKELETON OF A PTERODACTYL

ONE OF MARSH'S MOST INTERESTING DISCOVERIES.

THE PROPERTIES OF STARS IN THE SOLAR NEIGHBORHOOD

By WILLEM J. LUYTEN

HARVARD COLLEGE OBSERVATORY

The number of stars now known and the variety of their physical and astrometric properties which are open to observation are so great that we can no longer proclaim as the ultimate goal of astronomy the complete and detailed description of all the individual stars. This truly Herculean task has been considerably lightened by the application and introduction of statistical methods into the study of astronomy. And thus we put the science of statistics to its legitimate use: the combination and discussion of all observed data for the purpose of finding the general average of the universe.

As one of the principal objects of stellar statistics we may therefore consider the study of the properties of the average star in relation to the properties of the sun. It has long been known that the number of intrinsically faint stars in space is very large; accordingly it will be very difficult to obtain a representative sample of the stars in space, since these feebly luminous objects can not be detected unless they are very near us and may appear to us comparatively bright. If we limit ourselves to the immediate vicinity of the sun, we have the largest chance to find a few of these stars of low candle power.

Tabulations and discussions of the stars nearer than a given distance have been made by Hertzsprung and Eddington. With the wealth of parallaxes, as measures of stellar distances, which have come to hand during the past few years, a repetition and extension of such investigations is not without value. The writer has recently published a discussion concerning stars nearer than ten parsecs[1] and has also considered, in less detail, some properties of the stars nearer than twenty-five parsecs. Somewhat similar studies have been made by Haas and Lundmark.

The greatest difficulty immediately presents itself while compiling the material and lies in the necessity of avoiding misleading effects of selection. Unfortunately, the selection itself can not be avoided, and a great deal of time and energy has to be spent in attempts to make an adequate correction for its influence.

It does not seem necessary to describe in detail the methods employed in compilation, and it will suffice to state that, in addition to the directly measured parallaxes, statistical parallaxes obtained by a variety of methods have also been used for segregating those stars which are nearer than ten parsecs.

The list thus obtained is, in all probability, complete for stars of the same intrinsic brightness as the sun or brighter. The selection factors operative for the intrinsically fainter stars, as a result of favoritism shown by observers to stars of large angular motion (which is almost the only property through which a star can betray its proximity to us), are such as to increase disproportionately the number of stars of large linear motion across the line of

[1] A parsec is the usual sideral unit of distance and equal to about 3×10^{13} kilometers.

sight. At present we have no criterion by which we can discover intrinsically faint, slow-moving stars, and our list is probably woefully incomplete for such objects.

The final list of stars within ten parsecs contains 104 entries, double and multiple stars being counted as one, and 144, if the components of such stars are counted separately. The apparent brightness, the distance and the proper motion (the angular, annual displacement in the sky) are known for all these, spectral classes have been determined for 132 stars, and radial velocities for 85 systems. For about a dozen of the double stars among them we know the elements of orbital motion.

The incompleteness of even this small sample of stars is plainly evident in the comparison of the numbers of stars nearer than five parsecs and between five and ten parsecs. The respective numbers known are twenty-seven and seventy-seven, whereas the portions of space through which these stars are scattered are in the ratio of one to seven. Hence we conclude that less than one half the expected number between five and ten parsecs are as yet on record. Making allowance for these undiscovered stars, we might state that in the solar neighborhood there occurs, on the average, at least one star in every twenty cubic parsecs of space.

Immediately passing to a statistical description of the distribution of the principal properties, we begin by considering the intrinsic luminosities. According to Kapteyn, the distribution curve of the absolute magnitudes, quantities corresponding to the logarithms of the luminosities, should be similar to a normal error curve; our data, however, show a marked departure from this symmetric form of distribution. The discrepancy is in the sense of a rapid increase toward a maximum frequency and a slow falling off afterwards. Giving due consideration to the selection inherent in the present material, this points to a significant excess of absolutely faint stars over the number predicted by Kapteyn. Additional evidence derived from the lists of faint stars with larger proper motion, published by Wolf, also indicates a decided excess of feebly luminous stars.

Kapteyn's normal error curve for the distribution of absolute magnitudes had its maximum at 7.7, corresponding to a luminosity eleven times fainter than that of the sun. For purely practical reasons, that is, for convenience in statistical description, it seems best to retain the analytical form of his curve for the present. Fitting such a curve to our data we now find the maximum frequency at absolute magnitude 9, corresponding to a luminosity forty times fainter than that of the sun.

It has long been known that a relation exists between the total luminosity of a star and its spectral class, which is a measure of the temperature, and therefore of the surface brightness. In the diagram are represented all the stars for which accurate data are available; the ordinates measure the logarithm of the intrinsic brightness and the abscissae measure the spectral class on the Harvard system, where A corresponds roughly to a temperature of 11,000 degrees centigrade, and M to 3,000 degrees centigrade. The stars represented by the three dots in the lower left corner are notable exceptions to the general rule that decrease in luminosity is connected with decrease in temperature; for the other stars, however, this rule appears to be almost in the nature of a one-to-one correspondence.

As has been mentioned before, it has been possible to derive the complete elements of orbital motion for some double stars. Using Kepler's third law of planetary motion for a comparison be-

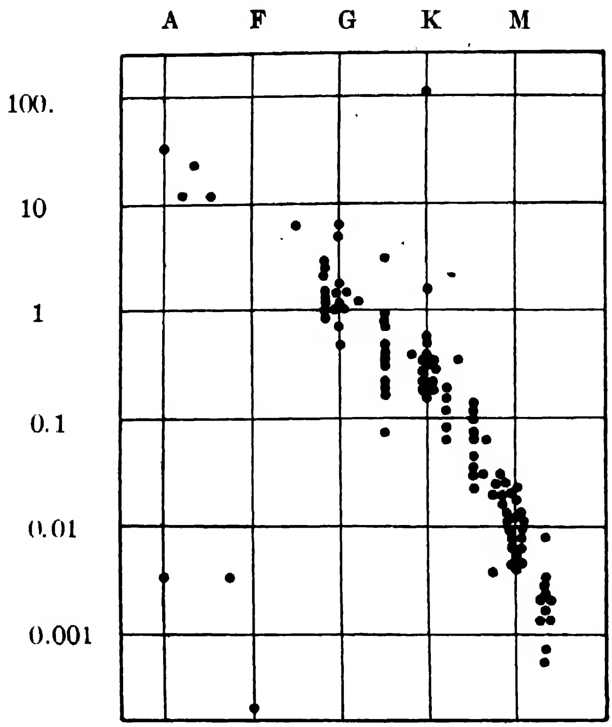


FIG. 1. THE RELATION BETWEEN SPECTRAL CLASS, AS A MEASURE OF TEMPERATURE AND INTRINSIC BRIGHTNESS, INDICATED AT THE LEFT OF THE FIGURE, IN TERMS OF THE SUN'S LUMINOSITY AS UNIT.

tween the sun-earth system and these double stars, their masses may be calculated. A provisional relation between mass and luminosity is thus established in good accordance with the results derived by other investigators. The curious fact is shown that, whereas the luminosities of the stars differ enormously, at least in the ratio of one to one billion, the differences in mass are much smaller, probably not much exceeding the range from one to one thousand.

Owing to the fact that stars with large angular velocities are more easily discovered and that more attention is paid to them by observers of stellar distances, the list used in the present investigation contains a preponderance of stars with large linear velocities and is not a true image of the condition in space. In spite of this, it may be of interest to examine the distribution of these velocities in size and direction.

The linear three-dimensional velocities have been computed from the radial velocities, the angular proper motions and the parallaxes. All motions are measured relative to the sun. It is not surprising to find, therefore, that the distribution is not isotropic, *i.e.*, not at random in all directions, and the obvious explanation of this circumstance is to attribute space motion to the sun.

The usual procedure in determining this solar motion is to assume it to be equal in size and opposite in direction to the apparent motion of the geometric center of gravity of the stars in question, obtained by assigning the same mass to all stars. Now that we are able to deduce the individual masses of the stars

by means of the statistical relation between mass and luminosity, it is possible to determine the sun's motion with reference to the real center of gravity of these stars. An additional advantage of such procedure lies in the fact that there appears to be a statistical relation between luminosity (and, therefore, mass) and linear speed, in the sense that the less luminous (and less massive) bodies have a higher speed. Accordingly, our system of giving lower weight to the less massive stars minimizes the influence of the otherwise too preponderant high-velocity stars. The computations give us for the direction and speed of the sun's motion: R. A. 278°, Dec + 36°, V = 25 km/sec.

After applying a correction for this motion of the sun to the velocities of the stars, we obtain what we may be permitted to call the absolute space motions of the stars. Since we have thereby changed our locus of observation from the sun to the center of gravity of these stars, there seems to be no reason why we should continue to measure the velocities with reference to a system of coordinates defined by the earth and the sun. The nearest approach to a natural system of coordinate axes may perhaps be found by defining it in accordance with the symmetry in the general distribution of stars in space. If we select as Z-axis the direction perpendicular to the Milky Way plane (the galactic plane), this plane itself will become the X-Y plane. We still can choose one of the axes in this plane, and we may take it parallel to the direction of most favored motion among the stars in general. Referred to this system of coordinates, we find that the Z-components normal to the galactic plane distribute themselves in a curve somewhat similar to either a first or a second Laplacean error curve. The components parallel to the galactic plane follow a distribution very closely analogous to that of a first Laplacean curve in two dimensions. The logarithms of the absolute space velocities (the speeds) are found to distribute themselves very closely in accordance with a normal error curve.

With such a small number of cases as the present it is perhaps not relevant to try to distinguish between the various hypotheses advanced to explain the pref-

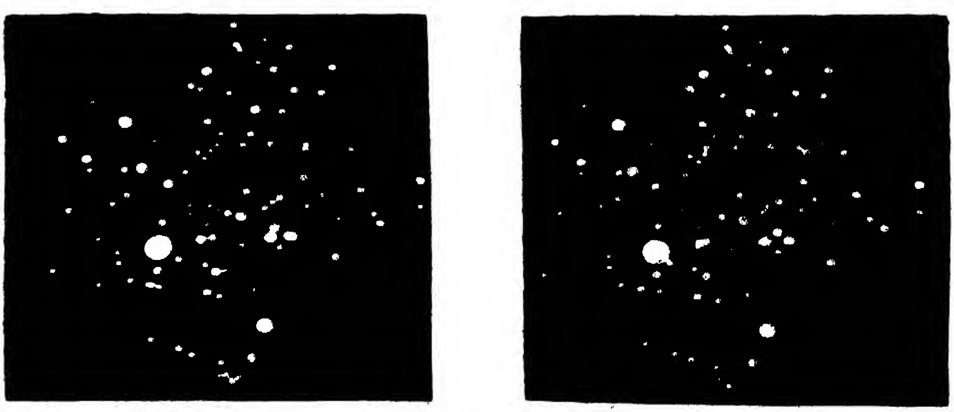


FIG. 2. STEREOSCOPIC VIEW OF A MODEL OF STARS NEARER THAN THIRTY-THREE LIGHT YEARS, AS SEEN BY AN OBSERVER SITUATED IN THE DIRECTION OF THE NORTH POLE OF THE MILKY WAY AT A DISTANCE OF APPROXIMATELY ONE HUNDRED AND FIFTY LIGHT YEARS. IN THE ORIGINAL MODEL A DISTANCE OF ONE PARSEC (3.3 L. Y.) IS REPRESENTED BY FIVE CENTIMETERS. THE DIAMETER OF THE SUN WAS TAKEN AS TWO CENTIMETERS AND THE DIAMETERS OF THE OTHER STARS ARE RELATIVELY CORRECT ON THIS SAME SCALE. TO BRING THIS RELATIVE SCALE OF STAR-DIAMETERS AND THE SCALE OF DISTANCES INTO MUTUAL AGREEMENT, ALL DISTANCES WOULD HAVE TO BE INCREASED ABOUT EIGHT MILLION TIMES.

erential directions of motion of the stars. The only significant fact worth mentioning is that the motions of these stars, rather than exhibiting an axis of preference, very clearly indicate an axis of avoidance which is perpendicular to the plane of the Milky Way.

Numerous relations of statistical importance may be derived from the material on nearby stars, especially by making use of the auxiliary quantity H, a function of the apparent magnitude m and the angular proper motion μ, defined by the equation $H = m + 5 + 5 \log \mu$. There appears to exist an extremely close linear correlation between this characteristic and the logarithm of the intrinsic brightness, commonly called the absolute magnitude. Otherwise interpreted, this relation signifies a statistical increase in linear speed with decreasing luminosity.

From the total space velocities and the statistical values for the masses we are now able to derive the individual kinetic energies. Choosing the sun's mass and a velocity of one kilometer per second as units, the mean kinetic energy is found to be 2,800 (that of the sun being only 320). In C. G. S. units this corresponds to 5×10^{46}.

With the aid of the black-body radiation formula for the angular diameter of a star, and from further scanty evidence concerning the surface temperature and the specific density of the stars, we can compute the average values of various astrophysical properties of the stars in the solar vicinity, and thus roughly construct an "average" star. We recall here that we found that, on the average, one star occurs in every twenty cubic parsecs, which is equivalent to 54×10^{40} cubic kilometers. If, for an illustration, we represent this "mean free space" by a sphere of 1,000 km. radius (*i.e.*, a reduction of fifty billion to one), then the diameter of the star endowed with all average properties would be 16 mm, and the mean distance traveled by it in one year would be 3,400 mm. The average temperature (unaffected by the reduction) would be 4,000°, and its mass about four grams.

Reasoning further and treating all the stars in the galactic system, assumed to number ten billion, on the same basis, we may compare our universe with a gas under exceedingly low pressure, so low that the configuration of molecules corresponds to that of the stars in our system. In this way, we can calculate that, in the entire stellar system, a collision between any two stars would not, at an outside estimate, occur more often than once in ten trillion years.

RELATIVITY AND ETHER DRIFT

By Professor W. F. G. SWANN

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In the discussions of the status of the restricted theory of relativity brought about by Professor D. C. Miller's recent investigations, the three experiments A, B, and D, cited below, have figured prominently, and, in our comments, we may well include C, which is an experiment falling in the same category.

A. Professor Miller's experiment itself. This is a repetition of the famous Michelson and Morley experiment and consists in sending two beams back and forth over two equal paths at right angles to each other with the object of determining whether a possible difference of ether velocity along the two paths will show itself by causing a difference in the times taken for the two rays to complete their journeys, the test being made by seeking a movement of the interference fringes, produced between the two beams, when the apparatus is turned through a right angle.

B. The experiment performed recently near Chicago by Professors Michelson and Gale. In this experiment two beams of light from the same source were sent in opposite directions around a large horizontal rectangle with the object of ascertaining whether any drag on the ether, due to the earth's rotation, would show itself by causing an alteration of that displacement from their symmetrical positions which the interference fringes would otherwise suffer as a result of the earth's rotation in a stagnant ether.

C. An experiment made by Professor Michelson in 1897, in an endeavor to test whether a change of ether drift with altitude could be detected. This experiment was fundamentally the same as B except that the plane of the rectangle was vertical, its horizontal arms being at altitudes as different as the limitations of a building would allow.

D. Measurements of astronomical aberration, *i. e.*, the angles between the true and the apparent positions of stars resulting from the fact that, owing to the motion of the earth and to the finite time taken for light to travel the length of a telescope, it is necessary to point the latter a little "ahead" of the star in order to obtain the star image on the cross hairs.

Experiment A has been performed at the earth's surface and on the top of Mount Wilson (altitude 1.7 km). According to Professor Miller it indicates an ether drift relative to the earth of 10 kilometers per second in the latter case, and zero drift in the former case.

Experiment B gave the same shift of fringes as would be obtained as a result of the earth's rotation if the ether did not participate in that rotation.

Experiment C gave no difference in the times for the two light paths and has been regarded as indicating no variation of horizontal ether drift with altitude, although it does not necessarily lead to this result, provided that such variation of horizontal velocity with altitude as might exist were combined with a variation of vertical velocity over the two vertical paths sufficient to provide for irrotational motion in the sense explained below. Apart from this appeal to the properties of irrotational flow, the

sensitivity of the experiment is such that a relative ether drift of one three thousandth of that predicted by Miller could have been detected, assuming the change of velocity with altitude to be uniform up to the altitude of Mount Wilson.

Irrotational Ether Motion and Optical Rays

The question of irrotational ether flow plays a very important part in the theory of experiments B, C and D, and it will be well to review in some detail the facts concerned with this matter.

In a homogeneous stationary medium the rays of light travel in straight lines except where they are reflected by mirrors; but even though the rays are reflected by mirrors, or travel in a non-homogeneous medium, or in a medium which is in motion, or subject to all these conditions, we know from the facts of optics that a ray which passes through two points P and Q pursues a path S between of such a kind that the time taken for the light to travel that path is less than that for it to travel any other path which joins those two points and lies immediately to one side or the other side of S. The path S is one of minimum time.[1] Now in general the path of minimum time between P and Q will be different according as the medium is stationary or is in motion. However, Sir George Stokes showed that provided the motion of medium is such that the average velocity taken around any closed path in the medium is zero, *i. e.*, provided it is of a type known as "irrotational," it will be without influence on the directions of the rays. It will influence the light velocity along them but in such a way that the alteration of time for all paths joining two points P and Q will be the same up to and including fractions of the order v/c of the whole time for the path, v being a quantity of the order of magnitude of the average velocity of the medium along the path considered and c being the velocity of light.

Now in all experiments such as A, B and C the position of an interference fringe is determined by the time differences for two rays emanating from the source and passing by different routes to the position occupied by that fringe. Since then irrotational motion of the medium will not alter this time difference to the first order of v/c, the position of the fringe will not be altered by such motion by an amount more than would be determined by quantities of smaller order. Again, irrotational motion would have no effect on astronomical aberration, since it has no effect on the directions of the rays.[2]

What, then, is the significance of irrotational motion, and why has this mo-

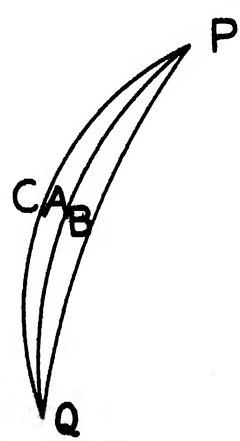

Fig. 1.

[1] In certain cases it may be one of maximum time; but in all cases it is such that a displacement of the path amounting to a quantity of the first order of small quantities in relation to its total length is accompanied by an alteration in time amounting to a quantity of only the second order in relation to the total time.

[2] There would be a very slight effect of the order v^2/c^2 resulting from the alteration of light velocity along the ray.

tion the remarkable property we have cited? Let us illustrate the ideas involved by considering the situation in relation to a ray PAQ, Fig. 1, passing from P to Q, there being, in the first instance, no motion of the ether. The path is one of minimum time, so that the times for any other adjacent paths such as PBQ, PCQ are greater than for PAQ.[3] Now if the medium is in motion, the velocity of light along any path at any point will be augmented (or diminished) by the component of the velocity of the medium along that path at the point. If the times for the three paths shown in the figure were increased by the same amount, the path which was one of minimum time when there was no motion of the medium would again be the path of minimum time when that motion existed. A very superficial examination of the situation shows that a whirling motion would not be the kind of motion to affect the light times equally. The sort of motion which would affect them equally would obviously be one which increased the light velocity along each path from P to Q, or diminished it along *each* path. Such a motion would be associated with a small value for the average velocity of the medium taken, in one direction, all around any path, such as PCQBP. As a matter of fact, it may be shown that a motion for which the average velocity around any path is zero is exactly the kind of motion which would alter the light times from P to Q along all paths by the same amount, and so insure that a path which was one of minimum time in the absence of the motion of the medium was also one of minimum time in the presence of that motion. A zero value for the average velocity around a closed path is the condition for what in hydrodynamics is known as irrotational motion. It is the condition for the absence of vortical motion, a motion which in its extreme form presents the features of whirlpools.

In forming conclusions as to what motion of the medium will do to a ray of light one must avoid using his intuition too freely without appeal to the principles involved in the above ideas. Thus, suppose the whole medium between the earth and a star were in motion with a constant velocity. One might be tempted to conclude that the directions of the rays would be different from what they would be if the medium were at rest. Such a conclusion would be unjustified, however, for the motion considered is irrotational in the sense that if we draw, for example, a rectangle two of whose sides are parallel to the velocity, these two sides would together contribute nothing to the average velocity of the medium taken around the rectangle while the contributions by the other two sides would each be zero.

In supposing that the motion of the

[3] For those who are interested in the more technical aspect of the matter the argument may be put as follows: If δS is an element of the path and c the velocity of light, the time is $\Sigma \frac{\delta S}{c}$ summed along the path. If now the medium is in motion and if v is the velocity of the medium *along* the path at any point, the time for the path will be altered. Since v is small compared to c, so that quantities of the order v^3/c^3 may be neglected it will now be

$$\Sigma \frac{\delta S}{(c-v)} = \Sigma \frac{\delta S}{c}\left(1 + \frac{v}{c} + \frac{v^2}{c^2}\right) = \Sigma \frac{\delta S}{c} + \frac{1}{c^2}\Sigma v\delta S$$

Now it is clear from the above that, if the motion of the medium is such that $\Sigma v\delta S$ is the same for any path joining P and Q, the times of all such paths will be increased by the same amount on account of the motion of the medium so that the path which gave the minimum time when the medium was everywhere stationary will also give the minimum time when it is in motion provided that the motion is of the type considered. If $\Sigma v\delta S$ is the same for all paths from P to Q, the value of this sum when taken along one path from P to Q and back along another path from Q to P will obviously be zero. In other words, the average value of v taken along the path will be zero, and, as we have stated, motion satisfying this condition is said to be irrotational.

ether, brought about by the earth's motion through it, is of an irrotational type we are confronted with a serious difficulty. The normal component of the velocity of the ether relative to the sphere has to be zero according to the ordinary ideas of fluid motion. But, with this condition assigned, it turns out that the solution for the motion of the ether everywhere else in space is completely determined. There is no latitude available to require anything else of the motion; and it turns out that the motion which the calculation reveals corresponds to a very considerable tangential velocity of the ether relative to the surface of the sphere. While this would not affect experiments B, C and D, since the whole motion is irrotational, it would affect experiment A as applied to the earth's surface; for the effect of ether motion sought in this experiment depends upon the square of the ratio of the velocity of the ether to that of light, and is not eliminated by the irrotational nature of the motion. In order to find some way out of this difficulty Planck tried to ascertain whether by making the density of the ether change with distance from the earth's surface, it would be possible to realize a condition in which there could be irrotational motion together with zero relative velocity normal to the surface, and an insignificant relative velocity tangential thereto. He found that the condition could be provided for by making the density of the ether in the vicinity of the earth about a hundred thousand times as dense as it is at a great distance, but it was necessary for him to suppose that this variation in density did not affect the velocity of light.

Thus the Stokes' irrotational ether with the Planck modification is consistent with B, C and D, and with the results of A as applied to the surface of the earth. It would also permit an ether drift relative to the earth at points above the surface, a fact demanded by experiment A as applied to the top of Mount Wilson. We shall presently discuss the question of whether it would permit a drift of the *magnitude* required by the Mount Wilson experiment. Another difficulty now arises, however, from the fact that if the earth carries the ether along with it in its orbital motion, we might suppose it also to drag it round in its rotation about its axis, and this would vitiate experiment B unless that drag were of an irrotational type, which it could not very well be, since it arises from the rotation of the earth. The way out of this difficulty was pointed out by Silberstein (*Nature*, Vol. 115, p. 798, 1925). Silberstein remarks "—our globe being almost perfectly spherical and having a purely gravitational grip on the ether does not appreciably drag it in its rotating motion —." Bold as this explanation seems, it is nevertheless consistent with, and indeed demanded by the hydrodynamical laws as applied to motion in a perfect fluid.

Discussing the effect of variation of ether drift with altitude in its relation to abberration, Eddington has remarked:[4]

> The difficulty is seen vividly if we consider the curvature of a ray of light coming to us from a star, taking account of this ether-flow. A ray which is vertical at the summit of Mt. Wilson will on reaching sea-level have an inclination of 7″. Thus observations of absolute star-position at mountain observatories and at sea-level will be discordant by amounts of this order. An error of the order 7″, variable according to the time of day, would play havoc with fundamental astronomy.

This result may be reached by combining the velocity 10 kilometers per second with the velocity of light, 300,000 kilometers, and so realizing an angle of deflection 10/300,000 radian, which

[4] *Nature*, Vol. 115, p. 870, 1925.

amounts to 7 seconds of arc. A word of warning must be given against making the conclusion appear too obvious, as one is tempted to do from the above line of reasoning. The conclusion is correct, but it seeks its strict justification only in the calculation of the displacement of the ray on the basis that the ray is the path of least time in both cases.

It is only in case there are no vertical velocities that the deflection 7″ calculated above is to be expected. As all agree, the seven seconds of arc deflection is annulled if the ether motion is irrotational. But, if the horizontal velocity is to increase from zero to 10 kilometers per second at an altitude of 1.7 km, the vertical velocities assume alarming proportions, as has been remarked by Eddington. Thus, to make the matter clear, suppose that all along the line ABC, Fig. 2, the horizontal velocity is

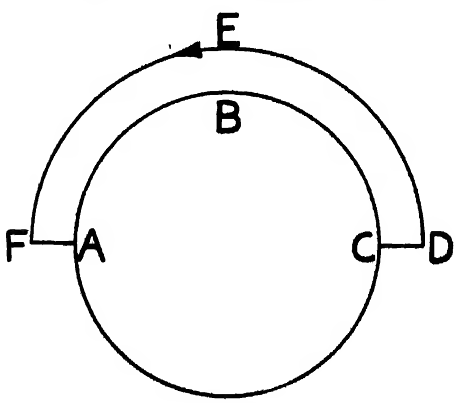

FIG. 2.

zero, and all along the line DEF at an altitude of 1.7 kilometers (the altitude of Mount Wilson) it has the value 10 kilometers per second.[5] Then, in order that the average value of the velocity along the path ABCDEF shall be zero it is necessary that the vertical velocities along AF and CD shall differ by an amount of the order U where $U \times 1.7 = 10 \times$ (semi-circumference of the earth in kilometers) so that U is about 10^5 kilometers per second, *i. e.*, about one half of the velocity of light. As a consequence, the actual vertical velocity along one of these paths must be at least as great as this. Of course the vertical velocity difference would be less in case we should draw the two lines AF and CD nearer together. In fact the difference would amount to only 5 km/sec if they were as close as a kilometer, but the emphasis on this point by Silberstein[6] does not relieve us of the objection that there would be a vertical velocity difference of the order of one tenth the velocity of light in the case of vertical paths such as these shown in the figure. A comparatively rough repetition of the Michelson and Morley experiment with the plane of the apparatus vertical should serve to reveal these vertical velocities if they exist as Giorgi has remarked.[7]

A further difficulty concerned with the change of ether drift with altitude has been pointed out by the present writer.[8] As is well known, and as has been remarked above, when the velocity of the ether relative to and normal to the earth's surface is assigned, the problem of irrotational motion is completely determined. Further, an examination of the analysis[9] will show that, even in Planck's modification of the theory with a variable ether density, directly the ratio of the ether density at the surface of the earth to that at an infinite distance is assigned, the problem is once more uniquely determined, and with it the variation of ether drift with altitude. Moreover, it appears that there is a definite relation between the relative velocity v_s at the surface and the change

[5] Of course, in practice the horizontal velocity could not be the same all along the line in question. However the figures used will serve for calculation of order of magnitude.

[6] In a letter to Science Service.

[7] *Nature*, Vol. 116, p. 132, 1925.

[8] *Nature*, Vol. 116, p. 785, 1925.

[9] H. A. Lorentz, "Theory of Electrons," pp. 314–315.

of velocity δv_s at an altitude h, this relation being $\delta v_s/v_s = h/R$, for small values of h where R is the radius of the earth. Thus, since $R = 6400$ kilometers, it is obviously impossible to have for $h = 1.7$ kilometers a value of δv_s corresponding to 10 kilometers per second, and at the same time a value of v_s which is small compared with this, or even not large compared with it.

To sum up the situation with regard to experiments B, C and D we may therefore say that provided that one is willing to admit absence of ether drag due to the earth's rotation for the purposes of B, while ether drag due to the earth's orbital motion is admitted, and provided that we are willing to admit a light velocity independent of the density of the ether, all these experiments may be harmonized on the basis of the Stokes Planck ether theory. Moreover, A could be harmonized as regards the sensibly null effect at the earth's surface; but the theory would then contain the power to deny any appreciable relative ether drift at an altitude of 1.7 kilometers such as Miller's results require on the basis of an ether theory. Quite apart from this objection, the very existence of a change of horizontal ether drift amounting to 10 kilometers per second for a change of altitude of 1.7 kilometers would involve vertical ether velocities amounting to very appreciable fractions of the velocity of light.

The Status of the Restricted Theory of Relativity

Of course, experiments B, C and D are consistent with the restricted theory of relativity, a theory in which an ether has no logical place and can at most occupy the position of an old pensioner who is retained out of respect for his faithful services, and because so many people know him, and for whom special provision has continuously to be made to keep him in the organization without causing trouble. Experiment A, as regards its results on the top of Mount Wilson, is, however, inconsistent with the postulates on which the restricted theory was founded. It is not without interest to inquire, however, as to how far the essentials of the theory of relativity necessitate those hypotheses. The vital thing about the restricted theory, the thing which is fundamentally operative, the thing which is of use, if it is only correct, and which is apart from all philosophical speculation as to the nature of an ether is the requirement that the laws of nature are of such a type that they are invariant under the Lorentzian transformation of coordinates.

Now let us transport ourselves in thought to the state of mind of the physics of fifty years ago, in which we suppose that there is a unique frame of reference to which the laws must be referred if they are to be true. Suppose it should so happen that the laws of electrodynamics as we have them to-day were true in that set of axes, and that the relation between that set and ours was such as the physicists of that day would have supposed on the basis of our velocity relative to that frame being about eighteen miles per second. If we in our set of axes should test the electromagnetic theory we should find it slightly in error if we could measure with infinite accuracy; but it would be necessary to measure our lengths and times to about one part in a hundred million in order to discover the errors. For we know that in terms of measures differing from ours by only this small amount, in terms of the measures given by the Lorentzian transformation in fact, these equations would be exactly right, apart, of course, from such matters as pertain to quantum theory. Thus, our measures would not be so far different from those of the Lorentzian transfor-

mation but that we should probably discover the equations of the electromagnetic theory, together with the force equation. When we had written them down on paper, some mathematician would discover that they were invariant under the Lorentzian transformation. This is a question of algebra and not of measurement. We should probably invent a restricted theory of relativity in which we supposed the Lorentzian measures to be the measures we were using. We should then form conclusions as to the variation of mass of an electron with velocity and proceed to form the Bucherer experiment. It is quite true that it is always possible to assign for the electron a velocity sufficiently nearly equal to that of light that the fact of our measures being non-Lorentzian would make as large an error as we choose to assign in our test of the formula. But we must remember that on the hypothesis that our formula was correct when measured in relation to the "fixed" frame, our measurements made in the moving frame could always be made to check the formula by altering them by quantities of the order of one part in a hundred million, so that an attempt to make measurements sufficiently near the velocity of light to show the errors in our units would cause the ordinary unavoidable errors of measurement to be of enormously greater importance than the departure of our measures from the Lorentzian measures. There is only one type of experiment which could hope to reveal to us that our measures were not Lorentzian. That is an experiment which could show up errors of the order of one part in a hundred million. Such an experiment is the Michelson and Morley experiment.

It is perhaps well to anticipate any criticism of the above remarks on the basis that in the case of motion the electromagnetic theory would itself suggest a contraction of dimensions in the electron, and indeed in matter in bulk. It is only on the rather crude electrodynamic picture of the electron moving in such a way that the total force on it is zero that the origin of the Lorentzian variation of mass with velocity seeks its explanation in a spherical electronic shell which contracts to ellipsoidal form when in motion. And as regards the Lorentzian contraction of matter in bulk, this is something which can not be predicted from electrodynamics alone without additional hypotheses, as is I believe now generally realized.

If there is a unique frame of reference to which it is necessary to refer the laws in order that they shall be exactly true in the simple form we know, then such experiments as the Michelson and Morley experiment, giving one result at the top of Mount Wilson and another at the earth's surface, must seek their explanation in a variation of the measuring system with the conditions under which the experiment is tried, and this without the necessity of any appeal to an ether theory. It is conceivable that the experiment performed in one place might give different results according as the rotation were produced in one way or another. The results would certainly be different if the rotation were produced with a sledge hammer; and there has always been an unsatisfactory element in the thought that all methods of producing the change through a right angle would converge to the same result for infinite degrees of "gentleness"; for it is not very easy to define what one means by an infinite degree of gentleness.

Nothing has been said regarding the status of the general theory in a situation of the above kind. The story in this connection is too long to enter upon here, but, in another place,[10] I have given

[10] "The Relation of the Restricted to the General Theory of Relativity, and the Significance of the Michelson-Morley Experiment." *Science*, Vol. 62, No. 1598, pp. 145–148, 1925.

arguments for supposing that the general theory can stand even if the restricted theory has to be abandoned in the sense in which it is ordinarily understood as implying the impossibility of detection of uniform motion relative to a unique frame of reference.

Finally, it may be remembered that, in the above, we have made no comment upon the validity of the experimental results of Professor Miller's work as affected by possible disturbing causes in the ordinarily understood sense. This is something on which much remains to be said. It is far too long a story to touch upon here; and, in the foregoing discussion it has not been my intention to adopt any definite attitude with regard to the matter but simply to examine the status which affairs would assume if it should turn out that the experiment in question gives a positive result when all disturbing influences (in the ordinarily understood sense of the phrase) have been removed.[11]

[11] In the April 30 issue of *Science* which has just come to my attention it appears that Professor Miller's most recent interpretation of his data is consistent with the view that there is no change in ether drift with altitude. Acceptance of this view would of course eliminate such portions of the foregoing article as are concerned with altitude variations.

SCIENCE AND MYSTERY

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Prologue: Antithesis and Paradox

The subject, "Science and Mystery," suggests a prologue; yet not for those whose reading must be only running.

It is a subject that belongs properly to a time, not of ordinary, but of extraordinary transition. In time of such transition look for many pairs of important factors and interests of life, just like science and mystery, in sharp and intimate antithesis. Look, too, as disclosing the intimacy, for many startling contradictions. Look for the anomaly, not merely in politics, but in life at large, of strange bed-fellows: for radical violence, it may be, sleeping with conservativism; poverty, with riches; perhaps offensive crime with respectability; even, as in case of close conflict of any sort, death with life. Look for the disturbed and fluent conditions, for the expanding meanings, or changing values, that make such abnormal things possible.

Times of extraordinary transition are as confusing to thought as to life. Listen, and you will hear men, of possibly more insight and sudden zeal than tact or humor, proclaim of things, long supposed different, and as cordially as mutually exclusive, that each really is the other. The rich are, say what one will, so very poor. Lawlessness, truly, is become the way of real law. In transgressors behold the real reformers; in those reputed wise the quite ignorant; and, again, in such as pay no income tax at all, the really wealthy. Topsy-turvydom, then, with a vengeance! Yet, of course, in a time of transition, and it be at all critical, as just now, that is just the right name for any region, where men of insight and zeal live and, as may be their way, while giving utterance to their paradoxes and feeling the strain of the charged atmosphere and the certainty of new alignments, cry or laugh over it all.

Forbear with me, if now I remember things. In an era of extraordinary transition, 500 B. C., came that sweeping seer, Heraclitus, who could hardly open his mouth, or take up his stylus, without mingling opposites, the hearing and the deaf, the good and the bad, even the cold and the hot. Was the Greek's world changing from one of sense to one of thought? Was Greek life getting new quality? Heraclitus came into Greek history when Greece was on the verge of Thermopylae, Marathon, Salamis, Plataea, and issues of value were indeed mixed with issues of force. To nineteenth century Christendom, when was that same mixing of issues, came two men, whom I now recall Napoleon's contemporary, Hegel, whose mental pabulum, the very staff of whose mental life consisted in antithesis and paradoxical synthesis, and soon after Hegel the great naturalist, Darwin, who substituted evolution for fixity and mingled extremest organic forms, as Bryan should "make note on," even more remote from each other than man and monkey, in the organic unity of all life. True, as some may contend, those men, the subtle old Greek and the distinguished moderns, may have been only sporadic products of history; their antitheses and paradoxes, spoken or implied, may have been rather accidents of personal reflection, unconnected with contemporary conditions, than pertinent and significant reports or comments on their times; but, not to argue as to that, at least it may be said that men of such insight and startling manners would be quite timely, when

great changes are under way, and that their utterances, however abnormal and even if accidental or in origin only personal and aloofly intellectualistic, do suggest actual vision and feeling for the contemporary situations.

It is true that at such times, in fear of losing station or some so-called "faith" or even money, many may still cultivate normal living and the simple thinking of "common sense," being bent on holding intact the *status quo* and all the vested comforts and satisfactions of it and not even hearing, although having ears; but, however great their number, they can neither prevent the general sense of preparing and impending changes nor, blinding the contemporary seers to the critical antitheses, stop their utterance of the disturbing paradoxes. Such seers and prophets, I take it, may easily be of the sort that are not without honor save among their own people.

Was it, too, only accidental and "intellectual" that for each one of those three abnormal thinkers, as in one manner and another he announced his strange insights, there was no stability anywhere, no immutability? All things were in flux, moving, flowing, evolving. Extremest differences were at best only relative and were constantly disappearing, revealing likeness after all, and were, moreover, no sooner reconciled or seemingly identified than they broke out again in novel ways, with changed meanings or values, on new levels. Syntheses, in other words, or adaptations, could be no more stable than differences and conflicts, and this besides. Complicating but greatly enriching all the issues of unity and difference, of synthesis and antithesis, there were the never failing but certainly most fortunate double meanings, the repeated values on different levels, and so the mixed issues.

Double meanings may bridge the worlds of sense and thought. They may bridge old and new. Bridging of some sort would seem to be their great function. I wonder, indeed, if there could be progress at all, biologically to new life, morally to better life, or spiritually to another life, without double meanings and their bold mingling of issues of value, or kinds, with the mere issues of opposition in kind. Doubtless a difficult view for minds with the set ways of practical "common sense" and normal commensurability; and many, possibly most, may not even care to try to understand it; yet, whatever meaning it may have to quite confirmed metaphysicians and cosmologists or even to the more sympathetic moralists, sociologists and the like, we all know that sometimes, quite in defiance of practice and common sense, it counts tremendously. The physically weak, for example, even among the wholly uneducated and uncultured, may be spiritually so strong. Yes, there are times when the profoundest subtleties count a lot even in ordinary life, bringing at least poetic harmony to a divided world. Could there be any unity of human society on any other plan? It may be quite poetic; but only if there be at least two different ways, one reactionary, the other progressive, perhaps one practical, the other idealistic, of loving and honoring one's country, can we all be patriotic. Existence may not need double meanings and mingled issues and poetry; but life and its progress would be mere existence without them.

Is special illustration of all this about antithesis and synthesis, paradox, double meaning and mingled issues, now desired? What comes to my mind may puzzle quite as much as it illustrates. *Similia similibus illustrantur.* The forbearance, too, already asked must be continued a bit longer. In Luther's time of transition, when beyond question things and meanings, or values, were in flux, how very different, yet how strangely alike, were spiritual and physical, or natural, become. So alike were they that it became necessary to separate them! How different were the Church's

spiritually confident but temporarily supported theocracy and the State's physical and militaristic but at the same time spiritually sanctioned monarchy; and, again, how also alike; how, to borrow not at all impertinently from the contemporary theology, consubstantial were the divine and the human, "of one substance" with each other. Emperors and kings had actually been raised—at the time a notable advance!—to the high level of popes, being hailed as *also* in their exalted offices "by divine right." The Church, too, had turned as worldly and Machiavellian as the State and in general the real authority or support of either was quite dependent on the very different strength of the other. So different, then, yet also so alike, were the spiritual and the temporal become.

To what result? What really did happen in history, as holiness, not only in the fourth to sixth century creed, but also in the sixteenth century institutional life, proceeded alike from the spiritual and from the natural or secular, *ex patre filioque?* What did happen? Luther and Machiavelli both assisting, as if two silent partners in a single cause, each acting from his different side, spiritual and secular were separated. So the historians have commonly made record. Only, somewhat to the confusion of the record, both State and Church, institutional representatives of the two, were so changed as they were separated that their divorce was possibly merely a fiction after all. It has ever been confusing to have things refuse to stay put, while one is saying wise things about them. The separated State became constitutional and democratic, recognizing the individual; the separated Church, Protestant and more personal, humanly personal, than institutional, the institution itself becoming ever more instrumental and adaptive; and each was thus raised into a region of new meanings, under which the two, albeit historically separated, were for their own later time still quite intimately associated. In very truth, whatever may be the manner of our thinking about history, the ways of history itself have not been simple!

The thirteenth to sixteenth century saints, I venture to add, had their interested and interesting part in that history and may bring more light in kind to a puzzling illustration. They were themselves such incongruous characters, mixing old and new, reaction and progress, as they did. Veritable paradoxes they were, done in human lives and purposes, at the time of Renaissance and Reformation. In them were met such separate and different elements. Were they only too faithful and reactionary Catholics or really potential and prophetic Protestants, forerunners of what was to come? Were they, again, spiritual zealots or only sensuous realists? Institutionalized mystics, literal and submissive, or disaffected individuals, humanistic and nature-loving? Watching them, as before, while watching the contemporary institutional life, we have to see, not merely some strange mingling of extremes, but also in process a real mutation of values. In the very fire of their zeal something old was being changed to something new. If any one objects, still insisting that they were essentially orthodox and only very reactionary, the reply is quick. Both the Church itself frequently called them to account with threats and persecutions, and also, as even more significant and as suggesting the cause of the Church's anxiety, in their own tense conservatism, as with their realism of sense they literally and personally reproduced the life and suffering, sometimes even the stigmata, of Him they worshipped, they did but betray the Church and involve themselves in the very movements or forces that were then active and were bringing the historic changes. The Church had a right to fear their spiritual loyalty but personal independence. Like so many others who at other times and in other

relations of life have grown tensely and assertively conservative and reactionary, those saints found and must now and again have keenly felt themselves, and still more they were seen of men, to be adopting and sanctifying the very violence which perhaps they had set out to bring to naught. The humor, conscious or unconscious, in the lives of the saints would make an interesting study!

To desist from further attempt at illustration and, if possible, even to forget Heraclitus, Hegel, Darwin and their whole tribe, there remains for this prologue, long as it has come to be, one thing more to be said. If the signs be right, our present time is very decidedly a time of transition, of more than ordinary transition. Few, if any, will dispute this even in 1926. During the war albeit not so openly since the late national election, we have been told so quite regularly, daily or weekly or monthly, as the various bulletins, the news paragraphs, the editorials, the essays, even the books, have been issued, reporting our time to us. Some of them, it is true, have sought rather to put us asleep than to arouse us; but such bulletins—or propaganda?—have come from persons or groups not themselves quite as complacent, or necessarily as righteous, as they would have others, who have sensed change and feared it, when not seeking also to exploit its conditions for their own advantage, and so have thought wise to dwell on prosperity and urge complacency. In such cultivated satisfaction can be no real evidence against present transition. Indeed, the real evidence may be just the other way. Moreover, for some years past the telltale antithesis and its unfailing and not less talkative paradox have most certainly been bulking large, giving—I say this without wishing to take the rôle of any mere alarmist—constant and effective challenge to all the bulletins, honest or intriguing, general or specific, for the *status quo*. As to the propaganda, too, and the conservatism of it, genuine or assumed, the more assertive it be, the more it must not only induce opposition, but also, quite in the way of those reactionary saints, actually do violence to the *status quo* itself and thus, however indirectly, end by bringing aid and comfort to its enemy.

How large antithesis, paradox and the ominous confusion of them have bulked in recent life and literature might profitably be made a matter of statistical research and subsequent serious reflection. Some years ago, as I recall, for a doctor's dissertation such a study was made of Coleridge, who was much given to antithesis. The conclusion was that Coleridge had used this and used it effectively as a literary device for expanding and reinterpreting the conventional ideas of whatever he was discussing or, in other words, for reproducing, in the form and movement of his writings, the conditions of transition and transmutation in life's meanings or values. For our recent and current literature, I believe, could the statistical study be made, the figures showing antithesis and paradox, movement and transmutation, would be impressive, if not also portentous. Our life and our literature have been simply alive with those things and the ferment of them. Essential factors or conditions or attitudes have been paired against each other and strangely mingled also and over and over again, only showing the disturbance and change, we have found ourselves strangely wondering, of two things sharply opposed, if there be any real difference after all between them or which of the two really is which. Most opposite things, I say, in our own recent life and thought have been thus most intimately paired: war and peace, of course; but also government and anarchy, capitalism and sovietism, nationalism and internationalism, reaction and progress, Fundamentalism and Modernism or—as only more general—dogmatic

idealism and naturalistic realism, and I venture not to say how many more such opposites at once so opposed and yet becoming so intimate. For nearly every one of them there already presses that question: Which indeed is which? Very much as the nationalists, to take just one case, after charging their opponents with proposing only a superstate narrow and nationalistic in spirit, however imperial, then justify their own policy of national isolation by arguing that so a powerful nation from its superior position can coerce or "hold up" the others, and as, on the other side, the internationalists at the same time discover among the nationalists, when judged by their deeds and policies, official and especially "unofficial," only a myth of isolation and so no pure nationalism after all, in short as those two opponents are thus mutually and hopelessly entangled, being each one on the other's side, just so and quite at large confusion reigns to-day. Everywhere old differences are breaking down; new are taking their places; values are changing; transition is the very life of our time.

And with all the other paired opposites of the time, assertively antagonistic, yet strangely intimate and exchangeable, we have those of our title, important as the others, setting vis-à-vis our reason and our faith, our knowledge and our dogma, our natural facts and our spiritual values: Science and Mystery.

Here endeth my too long prolonged prologue.

I

The Mystery of Science

For many of Christendom's years science and mystery have been in open opposition, notably in the warfare of science and religion. To-day, however, the opposition is nearing, if it have not already reached, a crisis, say even the inevitable crisis. Science is itself in an atmosphere of mystery.

In a way quite his own and, while not in all respects satisfactory, still suggestive and to some point, Bernard Shaw has given an account of the present situation.

> I affirm [he writes in the preface to his "St. Joan"] that the nineteenth century and still more the twentieth, can knock the fifteenth into a cocked hat in point of susceptibility to marvels and miracles and saints and prophets and magicians and monsters and fairy-tales of all kinds. The proportion of marvel to immediately credible statement in the latest edition of the Encyclopedia Britannica is enormously greater than in the Bible. The medieval doctors of divinity who did not pretend to settle how many angels could dance on the point of a needle cut a very poor figure as far as romantic credulity is concerned beside the modern physicists who have settled to the billionth of a millimeter every movement and position in the dance of the electrons. Not for worlds would I question the precise accuracy of their calculations or the existence of the electrons (whatever they may be). The fate of Joan is a warning to me against such heresy. But why the men who believe in electrons should regard themselves as less credulous than the men who believed in angels is not apparent to me. If they refuse to believe with the Rouen assessors of 1431, that Joan was a witch, it is not because that explanation is too marvelous, but because it is not marvelous enough.

Now Shaw may strike many as rather too playful and superficial for quotation here. Surely credulity about angels is not of the same quality or purport as credulity about electrons. Granted; but also the two may not be as far apart as at first seeming to be. To every time its own wonders; and our present time of science, climax to an era inaugurated about in Joan's century, really is, as Shaw suggests, a time of wonders as no time has ever been. Our wonders may not be like those of her time; but also the context of life to-day is not the same. All things are relative. In any case, too, just here being the crisis, to which we have come and which must mark some great change in Christendom's developing romance, it is immediately in and through science, not apart from science or in opposition to science, that our day's mystery is coming to us. With all their long antagonism our science and our mystery are at last come to be most intimate, while the external mysteries that

once held our interest no longer satisfy us spiritually or even puzzle us intellectually. These objects of what we now call superstition or with less offence blind and pious faith, in sharp distinction from seeing and unfeeling science, are no longer mysterious, being given place in our attention only as they meet or fail to meet the current tests of truth or error. We simply regard them as explained or explainable. A New York divine, apparently hoping to rescue some of the old mysteries or at least to preserve the "religious" awe of them, in a recent essay, "The Vulgarization of Religion,"[1] urges a restoration of now neglected altars and bids preachers and other spiritually minded persons to abandon their scientific discourses, their "obstetrical sermons," their vulgar and secular ways, which only reason and utility can have prompted, and so save for man and man's religion the great mysteries of a cherished past. Those mysteries are so sacred! What matters their truth or error? Never so, however, may he or any other recover what has disappeared. Men may find mystery where it is, not where it was. Here doubtless is real humor, but not open to all: The one-time wonders of religion, or of faith generally, subjected even unfeelingly to rational tests! The truths of once cold science revealing a magic world, a fairyland, that challenges belief and calls Christendom out of its confining stronghold to new and profounder adventure! Science, nothing else, is become our day's wonder.

Were we really losing mystery to-day, were spiritual values quite out of date, any reference to humor would have been, to say the least, in bad taste, as well as very ill-advised, and we might well worry greatly, being left with no choice but really to abandon all the altars and let religion and all that goes with it give full place to calm reason and mere calculable utility and efficiency. Mystery, however, for life in general is to-day become greater and nearer than ever; profounder, too, and of finer, subtler quality, even as the life itself in its understanding and in its activities is profounder and subtler. If only men would seek it where it is to be found, not at some merely rebuilded altar and vain cenotaph.[2]

The rise of science has been like the coming of day. There were the dark ages. Followed the Renaissance, with mists and colors and hopes so like the dawn. Then, the clearer and ever higher rising light of knowledge and reason. Is the story too familiar to be told again? In briefest summary, a supernaturalistic theology and, for the life on earth, a theocratic and institutional absolutism gradually gave way to naturalism both in thought and in practical affairs. In the control of man's thinking natural mechanics first took the place of the theology and its mechanical but nature-aloof institution. Then Darwin's biology succeeded the seventeenth and eighteenth century mechanics, which at best had been rather formal, or even say institutional, than close and vital in its naturalism. To-day anthropology and most intimate psychology become freely and

[1] By W. J. Dawson. See *The Century*, September, 1924.

[2] Even while I have been writing, the sun's total eclipse of 1925 has come and gone. Has no wonder attended this? Wonder there has been; but it has been, not at the strangeness and the suggestion of some unnatural influence, but at the predictability. In former days mankind reacted to the strange and unnatural, to the "supernatural," in characteristic ways, with various ideas of reference and valuation. To the newer wonder, to the predictability and all that this means as to man's nature and his world, the reaction must be different, but not less real nor less adventurous. Up to the present time we have been on the whole so conscious of the passing of the wonderful and "supernatural" and the coming of the predictable that the really more intimate wonder of the new has for most part escaped us. Only now are we beginning to realize how we have been face to face with real wonder for a long time.

candidly natural sciences, have supplanted in primary interest the evolutional but on the whole still man-aloof biology.

So, with the passing centuries, has science risen over Christendom, slowly dispelling the early wonders and miracles of all sorts, bringing man, his reason and his will, into ever fuller accord with his world, registering successive steps in a progressive adaptation, become to-day in some sense even identity, of man and nature; until, what with the psychological revelations, on the one hand, and the contemporary discoveries of the physical and objectively natural sciences, on the other, announcing a new environment to us even as inwardly we have found a new self, the one time darkness seems dispelled. Specially noteworthy is the fact that with the rise of natural psychology, dramatic climax in the succession that began with theology, there has been developed a no less remarkable natural technology under which the method and manner of life have been greatly changed.

But what has been the result of science's rise and illumination? Greatly and increasingly exhilarated with the splendor of the moving day, we are now becoming dazed. Has the light possibly exposed too much? Just when we are seeing most, we find ourselves wondering anew. Just when our science is clearest and deepest, at once most intimately human and most comprehensively natural, many are making it also so realistic that it hurts. They are taking it so seriously that it loses its clearness and is no longer "scientific." Our very science is casting shadows, lengthening shadows. It is even changing to a veil or mist and, as never before, we sense colors of romance and imminent adventure. Dead but yesterday, mystery is risen again. "The evening and the morning" have been only "the first day."

The day's life, too, its conduct of life, not merely its science, is charged with mystery. Was life ever blinder, in spite of—or because of!—all the light and, as should now be said also, all the efficiency? Thanks to the illuminating and applicable science, thanks to the remarkable technology but just now alluded to, we now live so differently. Again the story is familiar, even trite and tedious; but may also be retold briefly. At the beginning of our era the environment open to organization and civilization had been so enlarged as to include no longer just one or another of the different and widely separated regions of the several ancient civilizations, but the whole region of the Mediterranean. In due course, too, ere many years had passed, northern and western Europe were added. In the earlier periods, furthermore, of the struggle with this expanded and ever-expanding environment, new and strange and disorganized, man naturally felt himself, as certainly he was, aloof and unadapted. He and nature were very far apart, as if realities of two quite separate orders, one material, natural or worldly, the other unworldly and spiritual; one in some sense without, the other within. Building his inner, spiritual order, then, as it were, out of the available material, his cherished memories, and erecting so, as was certainly both his right and his wise resort, a sublimated world, or habitat, not here, but yonder, not now but hereafter, and feeling this to be real and alive with all that had ever had positive value for him, he made it present and visible in the Christian Church at once heaven's earthly retainer and Christendom's first formal device, a sort of strategical retreat, in its struggle with that environment.

In the very aloofness of that device, I submit, in its supernaturalism which was never independent of sublimated memories, and especially in the insistent, however arbitrary and militaristic exploitation of earthly human beings and present, natural resources, there was distinct adaptive value; not clearly realized

at first, it must be said, but at least distantly sensed even at first and in the outcome, which only brought to fruition the adaptation so made possible, distinctly proved. Witness, if evidence as to either the foresight or the fruition be needed, the Western Church's sanctification of materialism and naturalism and humanism as shown in that trinitarian doctrine of consubstantiability or of the equal holiness of the Father and the Son, to which allusion was made in the prologue, and as subsequently developed, until not just the Son with the Father, as it were only in a splendid symbolism, but more generally and quite comprehensively and realistically the human and natural were equated with the spiritual. So was the splendid symbolism fulfilled. As early as the ninth century, too, appeared the secular State, also already mentioned here, which claimed and got equal authority with the Church. Historically, the Holy Empire, the divinely appointed king, the pantheism of such as Bruno, and other paradoxical syntheses of spiritual and secular, divine and natural, really had very different meanings from those now often assigned to them. They all meant progress.

With such sanctification and elevation of the natural and secular there set in a process that has brought to us our very different life of to-day, effecting even a radical change in the basic instrumentation of technique of the whole life of Christendom. The earthly state and natural science, secular authority and natural law, came into Christendom together and grew up together; and with them came also objective machinery. Primarily, with whatever vicissitudes and disturbances, the State has done more than just appropriate and use; also it has, with application of the acquired and ever increasing knowledge, directly and deliberately developed its natural resources of all sorts. Wherefore, out of the natural environment there has taken form a most efficient natural mechanism, wonderfully fabricated and wonderful in its power and virtual intelligence, a mechanism of accurate registration and quick communication; and now for his adaptations man lives not so much with benefit of the old, aloof, spiritual institution as technical medium or instrument of his activities, as with benefit of his new and very different medium. Once Christendom "belonged," body and soul, directly and intimately to the aloof and supernatural institution; but its "belonging" or real membership to-day would seem to have been transferred, in effect, if not nominally, say *de facto,* if not yet *de jure,* to the new natural mechanism, the great communal complex of adjusted and cooperating modern machines and instruments of all sorts, now with minimal human effort doing man's work and even much of his thinking for him. "Automatically efficient" some are calling this mechanical system; and also "foolproof." In its day and its way, of course, the old institution was both automatic and fool-proof; but how much more comprehensively so is our new instrument. Direct man-power, militaristically mobilized, has simply given place to objective nature-power mechanically controlled and applied; and, on the whole, both the efficiency and the security have been increased many times. The earlier instrumentation through the institution may still survive in form or shell; also it may still be important for certain ideals and purposes that it fostered or say for the great spirit of it as something quite surpassing the letter; but life itself to-day, as to its instrumentation, is directly with benefit of the new and very different medium.[3]

[3] With benefit of the new medium, I have just repeated. The benefit may prove more profound than many will at first suspect. With the new machinery, be it not forgotten, has come new and startling exposure of human nature and the two together, the automatic efficiency of the one and the intimate illumination of the other, can not but react on morals

And, as in a former essay,[4] I have thought to show and, spite of a certain difficulty that will have to be met, would now specially emphasize, the present mechanical instrumentation of our life in reality has only grown, however gradually and through whatever dramatic eras, out of the earlier. I mean that the later has been only a development of the earlier, not coming by substitution of something quite new and unrelated, but coming by advancing realization of what was, by native expansion and generalization, by a progressive realization of the original spirit. If there be any logic, or say rather any social psychology, in the sequences of history, membership in the earlier mechanical and mediating institution, God-directed and man-powered, just because of the aloofness and the accompanying human directness, must have been training for the greater freedom of our present social life with benefit of the objective, humanly free, natural mechanism, the "Iron Man" or Giant Automaton, by which the institution has been followed.

The nature of that development has seemed to me to be well presented in a simple story from the nursery, one of my "twice-told tales." A child once suffered a bump of his head against a table and at once, poor and uncivilized fellow, hit back with his head. Later, however, getting another bump, he threw one of his blocks, instead of his head, at the offending furniture and so, as I see it, exhibited in the small what in the large has made our modern and, let me also call it, head-saving and block-using civilization. The distinct advance of the child's second method over the first is obvious. I think also that no one will deny that the latter instrumentation was, spite of its important difference, only an expression of present but unrealized elements in the earlier. Of course, not just for one individual or another, but socially, corporately, as if remembering its institutional life, Christendom has to-day adopted its block-using, vicariously instrumented civilization.

My nursery tale might be analyzed for many points of analogy; but its main point has been shown and will suffice, except that it also offers help against a difficulty to which I have alluded. Save for a certain difficulty, it was said above, our present life of machinery could be seen as the only development, not displacement, of what went before. Non-human, impersonal machinery has very largely supplanted the God-caused and God-moved as well as man-powered institution of earlier times and, just because of this, there are many who have found or will find difficulty in seeing the change as at all like real development. Is it not quite the opposite? Does it not show, as something that spoils the whole picture, a hopeless loss of personality divine or human? While I can understand the question, emphatically I think not. Did that child lose personality when he withheld his head and used the vicarious block? Truly, he grew greatly in personality. He may have lost certain physical feelings of himself and in general become less dependent on immediate and superficial evidences of self; but in both depth and reach of life, in character and power, he had advanced in a long, important stride. Taught by that child, then, I believe we may now dis-

in important measure. It is only a single illustration of this that the automobile is to-day offering a more powerful influence against drunkenness than the Church was ever able to effect. Supplemented by certain principles, biological, psychological or psychiatric, of eugenics, this influence may seem, even to the most ardent exponents of individual liberty, to give point to the recent legislation. The legislation may or may not be a bit ahead of public opinion, but in view of the benefit of which I have been speaking its justification is at least among the nearer possibilities.

[4] "The Time of Day," in THE SCIENTIFIC MONTHLY, October, November, 1924.

miss the objection or difficulty of lost personality in our modern life. The more instrumentation our life enjoys and the more objective or impersonal, as well as the more automatic, the instrumentation, the greater and profounder the personality. Moreover, as we live together, socially, corporately, with benefit of a highly efficient instrumentation, like that of to-day, our personality is real as well as rich. Personality can not be physically just a matter of bruises and inflamed swellings or mere immediate sensuous conditions or contacts of any kind; nor can it any longer be spiritually only what would be merely the negation of such physical being. In our day of automobilic machinery, say of the airplane and air-mail and the lighter-than-air radio, personality, physical or spiritual, must somehow be something else; to-day, then, not lost by any means, but "risen," more real than ever and immensely enhanced. Our Iron Man is only going forward, or "carrying on," for the medieval institution in respect to personality as well as in respect to instrumentation.

Mystery, however, not personality, was our interest. Having said that the very light of our time, the science and its most penetrating exposure at once of innermost man and of innermost nature, had actually made mystery, when it seemed quite dead, live again, our evening and our morning being only a first day, I would now add that the great change in the instrumentation of life, the nature of which, even to its consequences for the personality of every one of us, has been pointed out, really carries even more striking suggestion of mystery. Belonging as we do, each of us, to the great mechanism, primarily nature's, secondarily artificial in the Giant Automaton, possessed of remarkable speed and power and wonderfully automatic and fool-proof, we simply must feel ourselves, not merely members of the great system, but also real parties to the modern adventure of it. With our modern adventure, too, that of the forerunning institution can not be compared, although fortunately for present interest, always dependent on continuity with the past, the new is, as was indicated, but outgrowth of the old and the Church's romance can have nothing to lose; rather has it everything to gain, from life's adventure in its present vehicle.

Vehicle? Nothing else. Are we taking a journey to-day any less truly than in former time? Is our present journey taking us into a new world or a new life any less truly than the pilgrimage of the Middle Ages? And this also, at least if that difficulty was really met: Can our day's adventure be any less truly an adventure of personality, human or divine, than it was then?

Pessimists, who defy the day's charged atmosphere, for which nevertheless they must have some feeling, and persist in recognizing only routine and idle automatism, need to read history. After all, automata, political or social or economic, have been set up before, although never before so effectively or so comprehensively, and have also bred their quotas of pessimists; but, when most automatic, they have brought something new, something in the way of revelation and creation. Mechanicalism and automatism may make episodes or present special aspects of history. They never tell all the history of any time.

II

Adventure and Valuation

What, then, of the day's journey? To what is the present journey taking us? This question and the mystery of it, thanks to science and the application of science, now confronts us.

Many there are who would insist that inquiries, either as to whence we came or whither we are going, are no longer pertinent. Simple, commonplace and

conventional folk may still be putting them, but such folk are not supposed to count, at least not among such intellectuals as my present readers. The stork is become only a common bird. Paradise has lost its place on the map. Yet, although I am hardly of the simple and conventional and although nothing so conventional as either stork or paradise, or as anything for which either of these might stand, is now in my mind, I must confess to a feeling of sympathy with those folk.

Let it be as idle as any one is disposed to have it to question whence we came; just to avoid argument or speculation on the point, biology and evolution may be assumed to have settled so much; but, in view of our time's mystery and real adventure, there is at least pertinence in wondering, as we now move with the stars, whither we are going. This wonder, I insist, is pertinent; it is also pressing; and, at this writing, its real pertinence, its pressing timeliness, concerns me much more than any possible answer to it. I shall not even attempt to answer, being not without some caution. Nor, let me say at once, is the religious import of interest in what is to come by any means my whole concern. Before I conclude, I shall take occasion to speak of religion, since of course destiny is a problem of religion. My purpose, however, is more general. I would point out that with our present wonder about destiny, pertinent and pressing as this is, with our very science bringing mystery and adventure, we have now to put new and special emphasis, where for some time emphasis has been lacking or where interest has, to say the least, been perfunctory and conventional and in need of awakening, on the values of life in distinction from the facts, conditions or means. Mystery, romantic adventure and valuation seem to me to be quite inseparable. Let any one of them belong significantly to any time and I should have to look confidently for both of the other two. Facts call for explanation; but mystery invites valuation. Years ago I read in some book on knowledge that science, even modern science, concerned with facts and their rationalization, could be only a passing phenomenon. I understood at the time what the author meant and rather resented the probably not intended but seeming disparagement of science; but to-day I feel the meaning and know there is no disparagement. The passing may be nothing less than fruition through valuation in face of the resulting mystery.

A character or quality of the valuation should be mentioned here. Life-values, in distinction from objective facts and laws, are objects of the imagination, not of the understanding, or of the poetic and emotional mind, not of the merely knowing and reasoning mind. Valuation is most decidedly not calculation. Yet this is far from implying that it is idly or emptily visionary and sentimental. However formally beyond knowledge or reason, it has its dependence on them and its own insistent and unassailable realism. Indeed, at just such a time as our own, time of transition and confusion, of mystery and adventure, of double and incommensurable meanings, the bare facts and machinery of life have actually got too "objective" to be any longer real; they have turned too abstract and artificial to be adequate; and mankind, living reality rather than thinking or knowing it, is coming, albeit through knowledge and thought, into the experience, as real, of a super-factual world. The day's realism, then, a realism by valuation, while not formally just objective and scientific but appreciative and poetic, is so only because it would be, not abstract or artificial, but quite comprehensive and vital. For illustration of such super-factual and comprehensive realism from literature Plato's "Republic" may be mentioned; Augustine's "Civitas Dei," also; and even the possibly too romantic utopian social and

political writings of the sixteenth and seventeenth centuries. Such literature, of course, has ever been prone to abstractness in its own vision, and in any case at its time the complacent or alarmed conservatives can have little if any sympathy with it or with its "too poetic" and "quite impractical" idealism. But my contention is merely that it does make a true contribution to realism. In times of natural confusion and adventure, its poetic appreciation is profoundly opportune and may rightly claim to be realistic, not visionary. Also it must replace, as results of growth always replace, the prevalent and traditional systems of vision and value. It must be, I suggest, for its day and generation as timely as real, because enlightened, insight; as vital as genius; as powerful as the life or nature it is certain to release and mobilize. To deny realism to valuation, to allow realism only to "objective" knowledge, whether ordinary or scientific, is simply to betray real life. Not even for biology does "objective" environment exhaust reality.

Biological necessities, not to say other necessities of science and its thinking, such as anthropological necessities, have recently been much considered. The biological necessity of conflict, for example, has been a favorite topic, widely discussed pro and con, and would, I think, trouble no one if candidly associated with another biological necessity, that of growth or development. No specific type or level of conflict, low or high, can be, of itself, biologically necessary. Yet conflict may be so, if growth in the type, or level, be also recognized. Besides conflict, perhaps as incidents of it and of its growth, such things as romantic adventure, always preparing under any type or routine, and poetic, superrational valuation are also biological necessities, especially in the biology of human beings; and to these biological, or anthropological, necessities our time seems to me to be responding with special significance. We have, it is true, been in an era of prosaic scientificism and objective naturalism and through this era, except for many sporadic and inevitable outbreaks of social, moral and political radicalism, of atheism and other issues of unrest and protest and disillusion, we have been guided, our life has been motivated by traditional valuations inaugurated long ago. These have sustained our various social and religious, political and moral, economic and domestic orthodoxies and automata. But, to-day, we are come into the necessity of an active and direct revaluation. Even if we have to break with the traditional, at least with the letter of it, we must bring our world of values up to date with that of the now known facts and laws. The familiar issue of fundamentalism and modernism is only a special symptom, quite too feeble, as I sometimes think, in the candor of its modernism, of a very general condition. Our life is being challenged with many fundamentalisms.

Josiah Royce, lecturing and writing in the eighties, made much of observation, description and explanation, on the one hand, and of appreciation, or valuation, on the other. To both he assigned real and important rôles and he recognized the superrational or poetic character of the latter. Where life is, there must be both facts and values, conditions and purposes, to be reckoned with: facts, or conditions, and their rational unification in laws; values, or purposes, and their appreciative, even superrational, unification in ideals; and life itself can be real, not by either, but only as it is the meeting and functioning of them both.

Wilhelm Wundt, a contemporary of Royce, biological and psychological as well as philosophical in his interest, could admit no objective fact, or law, as found in experience, whether by the ordinary uncritical way or by science's more controlled way, that must not have, with its factual or rational character, also the

value of suggesting an ideal or norm of action. Found, something that is so and so: then, for the finder, something worth while or not so, something that may or may not be of value in the always adventurous life of action. Physically what goes up must come down! Who of us in his childhood has not shouted that out, so warning his companions to scatter, as he has tossed something into the air, and laughing quite irrationally at them as they have scattered? "Safety First!" is a familiar contemporary case of facts presented, at least by obvious implication, for their ideal or normative value. But always, be it kept in mind, the values, as assessed, are quite other than the facts and different. While the valuation, although sometimes slow in realization, must always attach most intimately to the world of facts and laws, it is nevertheless of its own kind and realm. Facts and values, again, are not commensurable. Real life, then, just by reason of the intimacy and incommensurability, has need of its poet-thinkers, not to say, too, of such as in their practical living also show those too incommensurables not really incongruous and perhaps for their rash, however romantic, "inconsistency" get roundly abused.

Since the eighties a good deal of water has flowed under the bridge. Valuation and its superrationalism—when not irrationalism—have far outrun Royce and Wundt. Various intuitionisms, the thirteen—more or less—pragmatisms, several behaviorisms, certain rather uncertain realisms or naturalisms, and other more or less destructive, more or less reforming and progressive attacks upon reason have had the effect of bringing the long increasing divorce of facts and values, of real knowledge and traditional ideals and purposes, to a crisis, by discrediting the traditional and virtually mingling valuation with knowledge, or, say, by bidding farewell to all subjectivity with one hand and, if I may quote from a certain novel, "loudly hailing" an enlivened and subjectified environment "with the other." Latterly, in other words, instead of being placed side by side with reason and science and treated as coordinate, valuation and the superrational, refusing any longer to stay outside, have entered in and taken possession. Their day, too, as I incline to believe, can be little more than just begun. As for the many reactionary movements, which might seem quite to belie what I have said, even these have been in the interests of valuation and so only testify to its rising importance. So far as reactionary, too, they simply sharpen the issue. Our values must accord with our facts! The traditional values to all intents and purposes are bankrupt; a receivership, doubtless, should have been declared long ago; but their very rush to cover is a sign and, in view of the bankruptcy, unless failure and death are to come to the life that is real and worth while, we must candidly appraise our modern knowledge and then with faith and courage launch whatever adventures in politics, economics, morality or religion may be indicated. Just this, nothing less, would seem to be the present duty, our day's biological or anthropological need; and to satisfy it all the various modernisms must boldly and strongly, not weakly, meet their respective fundamentalisms, political, economic, moral or religious, in kind; that is, not just intellectually, not by arguments as to fact or natural law, but with such values, with such quickening motives, as will actually sustain life to-day. By two things man may not live wholly and honestly to-day; mere bread and blind orthodoxy or normalness.

Finally, to speak directly and specially of religion, the pious and theistic are not likely to take too much comfort from what has now been said, although some will have caught suggestion of a possible religious revival not far off and so may hope for some justification. Yet emphatically a mere revival has not been

my meaning at all. True, in current literature there is a good deal to show that many are expecting something of the sort and so are readily responsive to any possible hint of it. Many, too, are thinking that if only, whether in the sensational way or with reserve and cultural dignity, there could be a revival, our troubles of the time would be largely settled. Progress, however, not revival, has been my meaning. Here has been no justification of any orthodox husks. In view of present conditions, in view of the now critical issue of new facts and old values, we must recognize and emphasize that any revival, which simply strengthened and made more assertive a reactionary church, could be only a sin against heaven. What right would religion have so, in time of need, to betray the life of its time? Something very like a reformation, not just a revival, is what is demanded. Only so can Christendom meet the challenge in the mystery of the time.

To those, who fear, as many doubtless will, the consequences of such a movement, it may be said that our time, as told here, certainly offers a possible case for theism. Has not the argument, almost from the beginning of this essay, been for a realism of values? Apart from other evidence or suggestion, the world of values has been found not only to be as real as the world of facts but also to be most intimate with this. What is that we call nature? What, but the real basis of the possibility of all facts and their unification in law! And what may God be? What, but the equally real basis of the possibility of all values and their unification in ideal and purpose! The facts, too, and the values, albeit incommensurable, are still, as must be said persistently, most intimate; even as intimate, if with whatever Christian spirit one may modernly as well as anciently take help from a Jew, as Benedict Spinoza found nature and God; and are also "of one substance" and equally holy.

Could theism ask more? I venture to say that it has sometimes taken much less. But is God still personal? Is man immortal? These questions were bound to come, belonging as they do to our religious traditions. Yet, I incline to leave them to the speculations of theology. Any uncertainty as regards them may be only a factor of our day's great romance. What now is personality? Or man, that we may continue to assert immortality of him? Our day's adventure, we should remember, among its other wonders is an adventure in personality.

We would do well to remember, too, that the personality of God and the immortality of man, as these have been accepted by Christendom, have been on the whole relative, or pertinent, to the instrumentation of life through what has here been called a God-caused and God-started but man-powered institution. Man has been a part of the institutional mechanism, living and moving and having his real being in the Great Cause or Mover; and personality and immortality have meant whatever they have meant in just this special context. According with this context the romantic figure among men has been the soldier, doing the will of his over-Lord and, whenever his time came, entering into his reward. But, to-day, as has been pointed out, the instrumentation of life has changed radically. It has become, relatively to the personality of the soldier, an impersonal and quite vicarious instrumentation; with the result, as may be submitted, that the real criteria of personality and so of immortality must have changed. The romantic figure to-day can not be the soldier; but, so at least it would seem, the mechanic. Should I preferably have said the engineer? Possibly; but, with apologies for the persistent militaristic metaphor, the mechanic belongs more to the rank and file. The mechanic, of course, has not yet come to his own and will still seem to most anything but romantic. The term certainly carries as yet little if any

thrill of romance, whether in life or in death. Nevertheless, the soldier of tradition is dead; long live the mechanic. And the latter, while a true person, is not such in personality as was the former.

So, not to go on with a discussion which can not fail to have interest, it must now be clear why I felt constrained to speak as I did of personality and immortality. Under the theism, for which I have claimed a possible case, even God's personality can hardly be what heretofore, to speak generally, it has been. Our day's adventure, I repeat, among its other wonders is an adventure in personality and, if theism must today, as at other times, give up certain outgrown anthropomorphic ideas, the reason can be, after all, not that theism can, or ever should avoid anthropomorphism, but that man himself is coming into a profounder understanding of himself and so theistically must value his new world accordingly.

All of which is so true, too, that it is plain enough why something in the way of a Reformation is a present need. With those who have been expecting a second reformation we must feel great sympathy. Yet what the articles or theses for it are to be, who can say? Dr. Fosdick, I recall, some months ago proposed fourteen; but I do not recall that he really indicated any such effective revaluation or reformation of Christianity as would seem to be demanded by life's new instrumentation and new romance. Good Protestants, appreciative beneficiaries of Luther's Reformation, ought not to object to another. In the sixteenth century there was distinct progress in substitution of an infallible Book for an infallible Institution and, among other results, universities and schools generally grew out of that change. Today the Book has lost its infallibility and the result, as it comes to be realized, may prove at least as progressive spiritually as that which brought the era of the Book. Always with progress there must be sacrifices. The Reformation of the sixteenth century exacted them and a new movement of the kind could hardly expect its sought progress without them in telling and in crucially testing measure.

Epilogue

As a last word, say a very short and a very simple epilogue, with which to conclude an essay that began with a long and not very simple prologue, it ought not to be hard for a would-be serviceable Christianity once more to meet the crucial test of giving up something. So often in times of transition the lesson that is at last to be learned is just the lesson that one has been teaching or preaching all the time and Christianity's original and persistent lesson has of course been that of sacrifice.

As with so much hundred-per-centism, those who insist upon holding on to every iota, to every jot and tittle, are very likely to find that they have really and hopelessly lost Alpha and Omega.

IN DEFENSE OF THE CAVE-MAN

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CHARLES LAMB, in the "Essays of Elia," listed several popular fallacies; a small number, indeed, of the great mass of misconceptions that are accepted as truisms by non-thinking people. A most popular and prevalent fallacy of to-day is that the cave-man was a mere human beast, a brutal mate, a cruel parent and a snarling menace to all weaker than himself. Teachers and preachers use his name to illustrate all that is low and bestial in humanity. Psychologists refer to the cave-man in us, when they discuss those primitive animal traits that have come to us as an inheritance of evolution. They would paraphrase Tennyson's lines to read:

> Move upward working out the beast
> And let the ape and *cave-man* die.

Novelists, desiring to portray a character, selfish, ruthless and brutally powerful, turn to this opprobrious term. Artists of humor sketch him as grasping the hair of his mate and in the act of striking her with a club. Hence, there has developed in the popular mind a savage *par excellence,* having no soul, no affection, no delicacy, no art, no chastity, no virtue. The cave-man dragged from his remote prehistoric past to be the scapegoat of the race has, symbolically, received the sins of all his descendants.

But now he has risen from his tomb (aided by the spades of the prehistorians) and demands justice to his memory and recognition of his virtues. He can not speak, but around him in his tomb and cave home are mute witnesses of his life and conduct.

The cave-men, in whose behalf this brief is written, lived in Europe twenty to twenty-five thousand years ago. By vocation they were hunters, by avocation artists. Physically they were superb specimens of mankind, of majestic stature, averaging nearly six feet, sinewy in limb, deep chested and with a large head well balanced on a muscular yet moderately slender neck. Their heads were long and their faces broad. From their skulls it would appear that their countenances had an Asiatic cast. Their eastern origin is further suggested by the fact that they were migrants into Europe.

Such were, in brief, the physical features of the pure Cro-Magnon race; a race, however, that in time came to have variations due to different geographic and climatic environment, and, perhaps, to racial intermixtures; for they roamed far and wide over western Europe, including the British Isles, then connected with the continent. Only in the Baltic and Scandinavian areas are no traces of them found, for this region was ice-bound during their occupancy of Europe.

It is far easier to picture them in the flesh than to follow them in their daily work and play and worship and to understand their outlook on life. Yet, with the abundant material now at hand, the task is not so difficult as it first appears. They left behind imperishable evidences of their industry and culture in the form of tools, utensils, weapons, ornaments and art. These humanly fashioned stone and bone articles have been aptly called the "fossils of the mind."

It is also possible to check these evidences of their habits of life by studying the behavior of modern primitive people living under like conditions and in a

similar stage of culture. For primitive minds often respond in a parallel manner to environmental forces.

We will never know his language, although we are positive from the shape of his mouth and chin that he was articulate and had advanced far beyond mere cries, screams and guttural sounds. As to property and government, if either existed, it was in a most simple form, since these men were hunters and never constituted a numerous population. But it seems certain that they hunted in packs and that certain caves were tribal property, or belonged to a priestly caste.

Neither can we expect to know much about their family system or methods of social control, though something may be inferred from study of modern savages. Their mythology, if they had any, must also remain a mystery. As to war, the witnesses are mute. Scanty as our field seems, much direct information is obtained as to their life and habits from the refuse of their homes, their art and their graves.

Let us enter these cave homes and examine the remnants of their life and industry that these homes have yielded to the picks and shovels of the archeologists. In some are found remains of family feasts with the charred hearth and the bones from which the meat had been eaten; in others are humanly fashioned tools, weapons and utensils, the "children of their minds;" in others are bits of carved or engraved ivory, bone and horn; some conceal, in their dark recesses, galleries of wonderful engravings and marvelous paintings in color; still others contain graves where the dead have been laid to rest with affection and with a firm belief in a future life.

Few caves produce all these documents of the cave-man's habits and occupations, but by piecing the scattered evidence together we may reconstruct a hypothetical cave home which will give us a fairly accurate view of the daily life and conduct of this long vanished race.

The first and almost universal feature of the life of the cave-man is that he lived in caverns and by the sides of rocky shelters. This habit, in his case, was due to the bleak climate which drove him to the sheltering recesses and caverns. Geologists tell us that the occupancy of Europe by the Cro-Magnon races was coincident with the approach, culmination and retreat of the ice-fields of the Fourth Glaciation.

This very fact was a spur to their social development. No longer could these hunters, who came into Europe from the mild Asian or perhaps African climate, camp where night overtook them; for the nights were becoming cold, and as generation succeeded generation the European forests and park-lands were dwindling because the moisture so essential to their growth was being locked up in the great ice sheets in the north. The winters also were becoming longer and the icy winds racing down from the frozen north were bitter and piercing.

Well might a grandfather say to his son's son that the climate was changing, and tell him stories, as they huddled together in a sheltered spot, of the days when the nights were balmy, the winds mild and the lands covered with park-lands, in whose leafy retreats the hunters found pleasant shelters for their families. Or he might tell them of the tales told him by *his* grandfather when the winters were short and mild and there was little of the white snow save in the mountains and highlands. As always with mankind: the old days were the better ones.

Little did these old men, who grumbled at the cold and change, realize that the very things they growled at would lift their race to higher levels. They did not, could not, know that adversity is nature's great whip to progress. Had not the ice-age interrupted the semi-

tropical climate that prevailed in Europe during the Third Interglacial period, it is extremely doubtful if European civilization would have risen so soon to the level of to-day. Look at the tropics! There is ease and animal luxury but little progress in all its years of human occupancy.

Stefansson has pointed out that the English Puritans migrated to the New World along two different routes. Some went to the bleak Massachusetts coast, others to the sunny, pleasant isles of the West Indies. The Massachusetts Pilgrims produced descendants that have been the intellectual and moral builders of the nation, while most of the descendants of those that went to the West Indies are now lost to view and have contributed little to progress. It has been proven time and time again that where life is easy stagnation takes place.

Let us consider the advantages that were obtained by the Cro-Magnon hunters who were compelled by a harsh and seemingly unkind climate to forsake the open and take up their abodes in caves. First and most important was the attainment of a home. This marks the beginning of ownership of real property and all that ownership implies. But the real benefit of cave life came from the establishment of the family group, that small unit which is the seed of the many-branched tree of all social systems.

To assume that no family life existed before the permanent home came into being would be a great error. For, much farther back in the history of man than our subject will take us, there are many evidences both direct and indirect that man lived in families. But it was the life in a permanent home that led the way to higher development in the social complex. The home marked a distinct advance in the division of labor between the sexes. The woman became a "stay-at-home" instead of wandering with her mate in his search for sustenance. This meant more time for domestic duties; children had better care and infant mortality decreased, thus increasing the population. More time was found for material culture and the woman learned much about cooking the game, cutting and sewing of skins and fashioning ornaments, long dear to her sex. To this leisure, and it was leisure in comparison to roaming with the hunting pack, modern society owes much.

Here we may introduce some evidence in defense of the cave-man, especially against that most prevalent charge that he was a hair-pulling, club-beating and cruel mate. It is true that the evidence will be purely circumstantial but somewhat convincing.

We must open the argument on the premises that the cave-man was a hunter, and men in the hunting stage require a very large quantity of game for their support. A large population of hunters would deplete the edible animals in a comparatively short time, and we know that Cro-Magnon man roamed over a restricted area, like France, for thousands of years.

Again, it was most difficult for these hunters, because of the primitive and feeble type of their weapons, to slaughter at will. It required much patience and hard work to bring down their quarry. We may, therefore, assume that the cave-man was a monogamist, if not by choice, by necessity, as a surplus of women would overtax his powers as a provider. Among nearly all primitive people, who live in the state of monogamy, the woman is the man's equal in the home. It is where polygamy flourishes that the woman becomes the slave and chattel of men. If then the cave-man was a monogamist, his mate, we may be sure, was dear to him, if not through ties of idealistic love, then through necessity. Without her there was no one to share the work, to do the many necessary things for which he had neither time nor inclination. He held her as his most important piece of prop-

erty, and when a man feels that way toward anything he will treat it kindly, whether it be a woman or a dog.

Another bit of evidence of her place in the home of the cave-man is that even to-day woman is the dominant sex among the primitive races that live in the remote, outlying regions of the earth. These races of "the fringe" retain to a greater extent than others the unadulterated primitive cultures that each race passed through.

With few exceptions polygamy is usually the result of wars, depleting the male population, or prosperity, through which men are enabled to buy wives, the number being limited only by the worldly goods of the purchaser. As no evidence exists that the cave-man engaged in wars or was rich in lands or herds, the testimony again points to his habit of monogamy. Hunters, especially those that live exclusively by the chase, seldom purchase wives, while those in the agricultural or pastoral state are the greatest buyers of women.

We have studiously avoided introducing any element that could be called emotional in defending the cave-man against the charge of cruelty and complete bestiality. Yet it is permissible to look at him as a human being and accord him natural kindness and even the glimmerings of conjugal love. For, if the gorilla will fight for his own and sit the night through with his back against a tree in which his mate and offspring are sleeping, we violate all the laws of evolution if we deny that sympathy and affection were totally absent from the breast of our ancestor of twenty-five thousand years ago. But, without reading pathos into the evidence, it has been shown that economic conditions and a natural balance between the sexes, with propinquity added, especially the latter, produced affection akin to love.

A mastiff dog
May love a puppy cur for no other reason
Than that the twain have been tied up together.

This same bond of unity and mutuality, which united the cave-man to his mate, extended to other members of his family and probably influenced the unity of the tribe. Stefansson says of the Eskimo, whose hunting, culture and harsh conditions of life resemble that of our European savage: "In a difficult struggle for existence under hard natural conditions they have acquired the ability to live together in peace and good will."

The advantages of the home life of the caves were many. There was introduced a greater opportunity for the leisurely development of the child. He had a longer time to profit from the accumulated wisdom of his parents and they, in turn, learned in teaching him.

If human development was purely a matter of attaining physical hardihood, the roaming life in the open with sufficient food would undoubtedly promote it best. But muscular development and physical prowess are not the whole end of man. The period of childhood should be the educative period as well as the time of play. "All work and no play makes Jack a dull boy" is as true when applied to the savage Jack as it is to the civilized Jack.

Perhaps here in the home the beauty of the human countenance was developed, for Giddings says: "A relatively long period of lactation, with inability to use food requiring strength of jaw, must have changed the facial angle and the expression of the countenance."

Without challenging or supporting this statement, it may be noted that the face of the Cro-Magnon man, with its high forehead, straight and high nose, slight protrusion of the lower jaw and well-developed chin, is much nearer that of the modern European than any other race of the Old Stone Age.

This hypothetical discussion of the home of the Cro-Magnon savage would not be complete without mention of the old folk of the family group. In the

days when the hunters had no fixed abode, the old and feeble must have been a drag on the tribe. But with the home came a refuge for the old. We know this to be so, for among the many discovered Cro-Magnon graves are those that contain the bodies of old men, buried by loving hands.

The preservation of the old meant much to the culture of the family, for here was to be found a longer experience, a reminiscence of life's lessons that added much to the stock of the family's knowledge.

Turning to the evidences of the material traits of culture that lie embedded in the débris of our assembled cave home, we find a great number of silent witnesses of the cave-man's occupations, industries, dress, utensils, weapons, tools and artistic nature.

It is at once evident that he was a hunter, as nothing has ever been discovered to indicate that he had even a rudimentary knowledge of agriculture or that he possessed any domestic animals. Toward the latter part of his occupancy of Europe he became a fisherman, whether this attainment was forced upon him through the depletion of terrestrial game or whether it was made possible through the development of the knowledge of working bone is not known.

From the bones scattered around the ancient hearths, it is estimated that over two score animals were hunted by Cro-Magnon man. Chief among these were the reindeer. These mammals occupied a similar position in the life of these ancient hunters as did the bison of the American prairies to the Indians of the plains. Obermaier says: "The flesh and suet provided them with food, the tallow with light and heat, the hide with clothing and covers, the horns and bones served various industrial purposes, and the guts and tendons were used for cord and thread." Indeed, they have well been called the men of the Reindeer Age.

Beside the reindeer, his favorite animals were the horse, bison and mammoth; the latter not only gave him food but supplied him with ivory from which he fashioned ornaments. This served also as excellent material on which to execute his remarkable ability as an engraver. His fondness for the horse is well shown at the prehistoric station of Solutre, near Macon, France. Here have been found, in an area of something over four thousand square yards, bones of over one hundred thousand individuals of a small breed of horses, and, as many of these bones are charred, it would seem that horse-steak, at least in this neighborhood, was the chef d'oeuvre of the Paleolithic cooks.

In the fashioning of utensils, implements and weapons the cave-man had progressed far beyond previous races. The growing necessities of life and the accumulation of inherited experiences had produced inventions that meant much in his mastery of nature. He was no longer the roaming hunter, the itinerant camper; he had become a householder, and that meant domestic duties which called for the invention of new utensils and implements.

One of the most interesting features of the stone industry from the standpoint of home life is that thousands of dressed flints and flint flakes have been found mingled with the hearth débris of the cavern home.

It thus becomes evident that these early homes were workshops, and we can well imagine that young and old engaged in producing the hunters' ammunition and weapons and the housewife's utensils. The latter were not as numerous as the former but much more varied than during the long human history that had gone before. Among the implements probably used by the housekeepers were stone-blades, for cutting of skin for clothing, scrapers, for dressing the hides, awls and cylindrical chisels for making eyelets, bone needles for sewing, and even buttons of bone and ivory, which were often decorated with the engravings of animals. Lamps made of

stone and resembling the stone lamps of the Eskimos have been found.

The knowledge of bone-working was a most important advance to the hunter as well as the homekeeper, for he was able to construct articles that were of assistance in using his stone and wooden weapons. One of the most conspicuous horn articles was the so-called "baton de commandement." This was made from a reindeer's horn at a point where branching occurs. At this point a hole was made. For many years its use was unknown, but it is generally accepted now that it was used to grip the shaft of an arrow in order to straighten it. These were often beautifully carved with representation of animals. Another interesting bone implement is the dart thrower, an implement used to lengthen the arm and to give greater force to the dart. These were also made from reindeer horn, though some were carved from ivory. Two, at least, have been found that have notches cut on them. It has been suggested that these grooves are tally marks and represent the number of times that the dart successfully reached its mark.

During the closing stages of the cave-man's reign, fishing seems to have largely taken the place of hunting, as there is a remarkable development in the making of harpoons. At first these were simple and crude but soon developed into an advanced type having a double row of barbs.

Such were the occupations of these ancient men. Their industries were as simple as their life was uneventful. They invented new things as necessity dictated. During the hunting season the men were on the trail, slaughtering as many animals as were needed for food during the long winter months, as well as for their skins which served as material for clothes, covers and perhaps curtains.

Although no evidence is available it seems most probable that they understood the methods of drying meat and curing it, for it formed the bulk of their food. They also must have prepared and stored the skins, for many of the animals, as the reindeer, had poor skins during certain times of the year.

The long winter cave-life permitted considerable leisure and it can well be conceived that this time did much to cement family ties and to develop the culture of the savage mind. Around the cave fire the family spent many long days, the men reciting incidents of the chase and putting into new words new ideas that had come to them. All this tended to increase the family's knowledge and each generation benefited by the experiences told around the home hearths.

The most outstanding cultural characteristic of the Cro-Magnon savage was his artistic temperament. His art is well known and reached a remarkable technique. This artistic ability was largely racial, for a vast number of objects have been found that would indicate by their very abundance that nearly every savage was somewhat of an artist.

Descriptions of the marvelous art of the cave-men will have to be omitted. It is sufficient to quote Cartailhac and Breuil, famous French archeologists, who say that the polychrome paintings of these men "place them far above the animal painters of all the civilizations of the classic East and Greece;" and Professor Osborn says: "These people were the Paleolithic Greeks; artistic observation and representation and a true sense of proportion and of beauty were instinct with them from the beginning." In the face of such evidence coming from highly educated men of the twentieth century, can we still think of the cave-man as a bestial savage with no thought save the gratification of his physical being and differing only from the brute in his upright posture?

From the standpoint of his defense we are more interested in the fact that he

was an artist of rare ability than in the enumeration and description of his art. His paintings prove close observation, keen intellect, the perfect coordination between hand and brain, a knowledge of contour and perspective, a sense of beauty and color; in short, his feeling of beauty and delicacy of expression stamps him superior to all primitive races and marks him as an equal of many civilized peoples.

A study of the evolution of this art throws much light upon the influence of home life and its hours of leisure and aids us in supporting the argument that the higher qualities of these ancient hunters were due in a large measure to the conditions produced through having a permanent habitation.

During the early centuries of the Cro-Magnon's dynasty in Europe when he was a wandering hunter his art was heavy, crude and awkward. The engravings were in absolute profile and stiff in form. The paintings were composed by merely filling in the engraved lines with a single color; there was no attempt at shading or blending the colors into tints. The few pieces of sculpture found are heavy, exaggerated figurines of the female form.

The later centuries of his occupation showed a vast improvement in the technique as well as a use of greater variety of material. He used bone and horn as well as stone and ivory. The engravings not only showed the outlines of the animals depicted, but fine lines were introduced giving contour to the forms and representing the hair of the body. In sculpturing are found models of animals in clay and high reliefs are carved on bone, horn and ivory. But the culminating glory of this ancient art is found in the polychrome paintings that adorned the walls of caves and appear as frescos on the roofs.

As long as the Cro-Magnon men lived in the open, before they betook themselves first to shelters and then to caves, they had little opportunity to develop their native artistic taste; they were on the move too much, and the bones of the slaughtered animals, which were the earliest materials on which they executed their art, were left behind as they went from place to place.

Thus, their first works were largely portable pieces or light engravings etched on the walls of shelters where they stopped temporarily. Later, the art of engraving was not only better but it was much more general, indicating more leisure time for all. Furthermore, in a permanent cave home a great deal of horn and bone would accumulate, and, during the long winters when hunting was at its ebb, the hunters utilized this waste material to fashion new implements and tools, adorning them with carvings. Here we find for the first time in human history man putting his thoughts and reminiscences in writings, for these pictures were the forerunners of script. His retrospective grew as well as his prospective. Whatever may have been the purpose of this art in the later days of the savage race, we can not doubt that in its beginning it was solely for expression of thoughts and was art for art's sake.

There is one other evidence of an advanced cultural stage in our hypothetical cave, and that is that the cave-man knew how to produce fire at will. It is true that fire was utilized by men who antedated the Cro-Magnons, but among the débris of those more ancient camps there has as yet been no evidence produced that the men of those days could build a fire when they pleased. On the other hand, in the Cro-Magnon homes are remains of their fire-building apparatus. Flint scratchers suitable for striking a fire from pyrites are of common occurrence in these times, and lumps of pyrites bearing the markings of the flint matches have been found.

We have drawn aside the skin curtains of the cave-man's home and looked

upon his family life and occupation and found, not a beast, whose only concern was food, shelter and the gratification of selfish passions, but a man who was kind to his mate, who played with his children, who shared with his neighbors the meat obtained by hunting, who took care of the old and buried his dead with affectionate care; a man who, beside being a clever artisan in stone, had a sense of the beautiful, of form, of color, and could express that sense in carvings and paintings; a man who, as he looked up at the stars shining clearly in the winter sky, wondered at their mystery and had that unutterable longing for touch with the Unknown.

Let us leave the living and turn to the dead. We have glimpsed the home, let us look into the tomb. Many burials of Cro-Magnon man have been found. He utilized caves for tombs as well as for homes. A large number of his graves have been opened, and their contents have given us not merely a knowledge of his physique but have thrown much light upon his faith and beliefs.

A description of one interment will give us a concrete example of the general method of burial.

In a cave bordering the Mediterranean, in Italy, near the French frontier, known as Barme Grande, one of the famous Grimaldi caves, a triple burial of members of the Cro-Magnon race was found. One skeleton was that of a tall man, one of a young woman and one of a young boy. All were lying in the attitude of sleep, except that the arms of the woman and boy were folded in such a way that the chin rested on the hands.

With these bodies were found ornaments and implements, indicating that the friends who laid them to rest also supplied them with adornments and weapons that they might be properly equipped for the life beyond. The ornaments surrounding the body of the man were numerous and most artistic.

On his skull were perforated deer teeth and joints of fish vertebrae, with a number of perforated shells of the genus Nassa, a whelk-like gastropod. It seems quite certain that the different materials were originally woven into a headpiece. Around his neck were the remains of a necklace composed of fourteen teeth of the red deer, perforated and engraved on their crowns, and fish vertebrae. Also there were large pendants of engraved horn. Near his left hand was a fine flint-blade nine inches in length and two inches wide.

The boy was similarly equipped for the death journey, for there are remains of a cap composed of the same materials as that of the man's, and a wonderful necklace which in its original condition was composed of a double row of fish vertebrae and a single row of Nassa shells. This triple row was interspersed at regular intervals with engraved and perforated canine teeth of the stag. There was also buried with him a flint-blade.

The woman, too, had ornaments, but not so many or as ornate as those of the men. At first this may occasion surprise, but among the less advanced savages ornamentation follows the rule of the higher animals, the male is the most highly ornamented. As if to atone for the lack of ornaments a very large blade had been buried with her.

In the trench where these three were interred was found a layer of red ocher. This same powder had been sprinkled over the bodies after they had been laid to rest. The result was that the bones were colored a pinkish red.

Let us interpret this grave in terms of human affection and faith. These very early men buried their dead. Such a rite is exclusively human, not being shared with any other animal. It implies that the body of a man is not regarded as a mere inanimate thing to be treated as the body of an animal.

Nearly every primitive race of to-day takes pains to either please or to guard against the departed spirit of man. In some cases the dead are buried with elab-

orate ceremonies and surrounded with costly grave goods. In others they are buried in such a way that their spirits can not return. This method is shown by binding the body tight with ligatures, or by burying it with the face down, or with heavy slabs lying over it. In fact, a few of the Cro-Magnon burials show these attempts at "binding the spirit."

Whatever idea animated the mind of the Cro-Magnons at different stages or in different individuals, whether the burial was to appease, to help or to control the spirit of the departed, it is very evident that they shared the almost universal belief of humanity that death does not end all. But from the general practice of laying the body in a sleeping position and adorning it with the most precious ornaments that the family could afford, and sprinkling it with the death-paint, we are justified in believing that the body was put away with grief and real affection.

> The scalping-knife beside him lay,
> With paints of gorgeous dye,
> That in the lands of souls his form
> May shine triumphantly.

Red is the color of life among a large number of savage races. Undoubtedly this conception arose from the fact that hunters learned that with the loss of blood death occurred. Hence, the logical step was to paint the body in death with the life-giving hue that the spirit might enter the realm of shadows with the symbol of life upon it. Or again its derivation may have come from the customs of hunters to paint their bodies red in imitation of the blood that they had received in killing the game, for much of the early hunting must have been at rather close quarters. This would stamp them as mighty men of valor in the chase. The first suggestion seems to be the most appropriate, as the bodies of women as well as men were so painted before burial. However, it is to be noticed that the Cro-Magnon children whose bodies have been disinterred were surrounded by offerings, but were destitute of the death paint.

This brief review of burial customs shows that the funeral rites were very simple and that affectionate care was taken to insure the welfare of the departed in the next world. This adds to the conviction that there was more affection than hatred and more love than fear among these people.

Imperfect as these evidences are of man's religious faith, we must remember that what remains of their convictions is only the material manifestation of their spiritual yearnings. As Ratzel says: "The profundity of the thought must not be measured by the imperfection of the expression."

A study of the art of the cave-man aside from its beauty, taste and realism, leads one into the belief that its later development at least had a close connection with his religious life. There can be but little doubt that his first works of art were done for the pure joy of expressing his artistic sense.

"Out of the love he bore them, scribing them clearly on bone." But later this art became involved in magic rites and religious rituals.

There are several salient features that are so common to all the later art that one can not avoid the feeling that more than art for art's sake was being expressed. Those magnificent polychrome paintings and forms moulded in clay were done in secret away from the public eye, for they are found almost exclusively in the remote and often inaccessible parts of caverns; they are usually representations of animals hunted for game or ferocious beasts; a great number show wounded animals with arrows or darts piercing them and blood flowing from the wounds; many of these animals, especially those who supplied the food, were so drawn or sculptured as to indicate the multiplication of the species; and, lastly, the works of art are representations of real life and not of mythical subjects.

The remoteness of the picture galleries from the family or tribal hearths indicates that the artists formed a special class who carried on their work in secret. The fact that there are many caves which are not decorated whose walls would have lent themselves very satisfactorily to mural pictures would point to the fact that certain caves must have been considered as temples and that those were the places where magic was consummated.

That so many of the animals depicted are shown with wounds and that others represent the multiplication of game clearly indicates that these pictures were meant as votive offerings to insure success to the hunter and to increase the fecundity of the game animals.

These men possessed little knowledge of astronomy, which figures so extensively in the pictorial art and religious rituals of many primitive races. They were exclusively hunters. Therefore, the sun was of much less importance to them than it was to the agriculturalists to whom it was the "life-giver," the quickener of harvests. We can thus account for the absence of the sun cult and the lack of a moon god, the deity of the seasons and the basis of most calendars.

The cave drawings are true to life. There has been no attempt to exaggerate nor to introduce strange and bizarre forms which is so often the case among men who have tried to express their religion through pictures. We find no evidence of combination of forms as the mermaid or the centaur, nor any conventionalized lines nor magic symbols which could be used to mystify the uninitiated. Indeed, from the location of the cavern galleries and their difficulty of access, it is very doubtful whether those outside of the artist craft ever gazed upon them.

It would seem, therefore, that the motives of the artists were sincere, that they really believed that such representations would have an effect on the hunter and his game supply, causing the hunter's aim to be sure and producing fertility in the animals which were essential to his very existence.

However strange a belief in the efficacy of pictures seems to us we can not help but feel that the realism of the art and its lack of hocus-pocus and the apparent absence of pretended incantations for the delusion of the masses, points to a real and honest endeavor to sway the unknowable for the benefit of the race. Is it assuming too much to consider this custom as a form of prayer? Certainly it is the expression of a dominant wish or desire.

> Prayer is the soul's sincere desire
> Uttered or unexpressed.

In this brief résumé of the material culture of these ancient hunters one can not escape the feeling that they were well above the average in savage mentality and that their culture, though extremely primitive and rudimentary, was characterized by a simplicity and purity that is not to be found among their modern representatives.

These later savages, although not much advanced in knowledge from their ancient prototypes, have accumulated a great mass of superstitions which have masked the original forms to such an extent that they have been almost lost. The primitive culture of to-day is so coated with the excrescences of voodooism, totemism, fetishism, taboo and witchcraft that it is badly diseased and its original purity defiled, not so much by any new element but by a cancerous growth originating from a normal culture but running wild and becoming an abnormal overgrowth. We should not read into the testimony left by ancient man the distorted development attained by modern savages.

If we think of these cave-men as men who were in the childhood of the race we can better understand them. They were crude and ignorant, they did not have behind them a mass of increasing

experiences, their growth toward civilization was extremely slow, but each laborious step carried them not only forward but upward; their life was simple and arduous; the climate, with its stinging goad, gave them little opportunity for slipping into degrading slothfulness; they had to meet and overcome the onslaughts of a pitiless nature. This constant battle with a changing and harsh climate sharpened their wits, developed their mentality by increasing their experiences. They grew and developed, while their kin, living in what seemed to be a better climate, "better" because life was more easy, have stagnated and remained stationary and, like a pool of stagnant water unstirred by any breeze, untroubled by any current, has allowed destructive life to grow from it until its surface has become covered by a decaying scum.

Social evils are not the outgrowth of primitiveness, they result from large populations. The cave-man had neither slaves nor concubines; these came with the acquisition of property. The pastoral and agricultural life produced wealth for the few and slavery or servitude for the many. Wealth and property incited envy; and war, raids and brigandage were the avocations of most tribal organizations.

No, it is not the cave-man whom we should blame for what is low and vile in the individual or society. His life was indeed a simple and primitive one, but it was as free from selfishness, greediness and all that constitutes "man's inhumanity to man" as any savage race of which we have any knowledge.

His empty hearths, on which no fire has been lighted for tens of thousands of years, speak of his domesticity, his opened tombs whisper of his affection and faith, and his art sings of his love for the beautiful and his humble and earnest attempts to conciliate the Unknown.

We find no evidences of his much bruited brutality or his lack of the higher human attributes. The cave-man was not a monster of bestiality, but a simple, kindly, happy hunter who toiled and struggled in the face of adverse nature, carrying humanity forward and living up to his best lights.

To him we owe much.

I and my brothers roam this rich To-day
Unhindered, unafraid, because thy feet,
Stone-bruised and heavy with primordial clay,
God's winepress trod to make our vintage
sweet.

BIRD LIFE ON MARGARITA ISLAND, VENEZUELA[1]

By AUSTIN H. CLARK

SMITHSONIAN INSTITUTION

Let us try to imagine ourselves to be where it is always unchanging summer all the year, off the northern coast of Venezuela, on the large island called Margarita, which lies about twenty miles directly north of Cumaná, midway between La Guayra and the island of Trinidad.

The island of Margarita gets its name from the unusual abundance of pearls yielded by the pearl oyster beds in the channel between it and the mainland. The island is about forty-two miles long, and is made up of two parts each with a high central peak, connected by a narrow neck. The eastern part is the larger and contains all the principal towns; the western is practically barren.

The island has three well-defined life zones. First, the flat and sandy coast region, which is exceedingly hot with the burning tropical sun almost directly overhead. The few plants are widely scattered post and melon cacti, with here and there dense patches of the dreaded "tuna," a kind of prickly pear with unusually long and sharp spines, and occasionally forbidding thorn trees. You can not really appreciate the "tuna" without an actual encounter with it. Its spines will go right through leather boots, and they are so brittle that the slightest contact breaks them off. All the animals of the region have spine tips in them, where the spines have gone in and broken off and the wound has then healed about the spine tip. The rabbits especially often have scores of spine tips in their flesh, but the birds have them, too, sometimes even in their eyes. You soon learn to dread the "tuna." The only attractive plant in this hot and barren region is a magnificent orchid, which is parasitic on the branches of the enormous tree cacti. This orchid bears a large pyramid of exceedingly fragrant flowers, which are at first white, but gradually turn brown. Sometimes there will be a number of them on the same tree and their fragrance is discernible for a long distance. The chief towns of the island, Asunción, Juangriego, Porlamar and Pampatar, are situated in this hot coastal strip.

Beyond the flat coast country there is an intermediate region of rough hilly country with a large amount of scrubby growth and many varieties of cacti.

The interior of the eastern part of the island is a heavily wooded mountain more than three thousand feet in height with its summit always hidden by clouds.

Several streams flow down the mountain and one, the most important, attains a considerable size in the rainy reason, flowing from high up on the mountain to the sea, which it enters a little east of Porlamar. In the valley of this stream at the base of the mountain is situated the little town of El Valle, in a large grove of cocoanut palms. It was in El Valle that I lived during most of my stay on Margarita.

I have never seen the booby gannets so abundant as they were in the channel between Margarita Island and the main-

[1] One of the series of Radio Nature Talks from the National Zoological Park, Smithsonian Institution; given January 30, 1926, from Station WRC.

land, and at certain times about Carúpano. They seemed to approach the land solely for the purpose of feeding, after which they withdrew to open water. Just off Carúpano there was a certain spot to which every day there came hundreds of sea birds of many kinds to fish. Over half of this congregation were common brown pelicans, and most of the rest were booby gannets. Overhead soared a score or more frigate birds, while various gulls and terns composed the remainder. All the larger members of this vast flock acted in perfect unison, wheeling about until a sufficient altitude was obtained, all diving with a great splash, then all slowly rising to repeat the performance. Every now and then a frigate bird would come swooping down upon some hapless gull. I was much puzzled at first to find a plausible explanation of the fact that day after day the birds collected in practically the same spot to feed. The water there was fully as deep as in the surrounding parts, and from the land no difference whatever was discernible. I thought I had found a possible clue to the mystery one day while I was watching some boys fishing off the end of the wharf. Every few minutes some fish or other, most often a sea catfish, would rise to the surface feebly struggling, to be almost instantly gobbled up by some watchful gull or frigate bird. I obtained a couple of these fish, but could find no marks whatever on them. The inhabitants told me that at certain times fish run ashore here by the cartload and say that it is due to large fish driving them in. It is noticeable, however, that when the fish run ashore in numbers there is always a smell of sulphur coming from the sea. This has given rise to the idea that sulphurous fumes coming up through the sea bottom poison the water. As this region is very rich in sulphur this seems a likely explanation. But it is not correct. What really happens is that when conditions are just right certain small plants in the sea, invisible to the naked eye, increase enormously in numbers. When conditions change these little plants die by the hundred millions and the sulphur in their decomposing bodies suffocates the fishes and taints the air above the sea.

Perhaps the most characteristic bird of the hot coast region of Margarita, certainly the one which most surely claims the attention of the traveler unused to the American tropics, is the buff-breasted parrakeet. One is never out of hearing of their incessant noise while near the coast, and little flocks of a dozen to twenty are continually passing and repassing. Although so very noisy on the wing, they become instantly quiet and motionless on alighting and are therefore very difficult to locate even in a leafless tree. They also show very great solicitude for a companion in distress.

Another interesting bird of the hot coastal region is the little burrowing owl. These owls are fairly common wherever the vegetation is scantier than usual. Near a large shallow lagoon where there is practically no plant life there is a colony of them. They are unsuspicious birds, and may be approached very closely before taking wing. They fly but a short distance, alighting with a series of bounds as if their legs were supplied with springs.

In this same region where the weird cacti and the parrakeets are the most conspicuous features, you hear from time to time a most familiar homelike sound which seems singularly out of place, the loud clear whistle of the bob-white or quail. In its habits as well as in its call this quail is very much like ours, and it looks much like ours, too, though it is provided with a conspicuous crest.

Other birds of this hot coastal region are the troupial, a large and beautiful oriole with a loud clear voice which it is very fond of using, the little scaled dove which when startled jumps up with a

curious sharp rattling of its wings, and a large hawk. Black vultures are common also, especially along the beaches.

In the rough and hilly scrubby country one of the most interesting birds is the buff-breasted hummingbird. In spite of its small size this is a very noisy bird, and in the early morning and again at dusk you hear its loud metallic song coming from all directions.

We have no bird which for pure stupidity and general lack of spirit can be compared with the two-banded puff-bird. With its large beak and its dark breast bands it suggests a clumsy kingfisher. It can be approached very closely before it takes alarm, and when it does fly it merely goes to the nearest available tree or bush and awaits the second approach of the intruder. Even when shot at it flies only a few yards and then alights as if inviting its pursuer to try again. Sometimes it does not fly at all, but remains stupidly staring at the cause of the disturbance. I have seen one shot without its mate, seated close to it, showing the slightest concern. The native boys sometimes kill them with stones.

In this region, as well as about the cacti near the coast, you often hear a cry much like that of the belted kingfisher, but harsher and more grating. This is the cry of the woodhewer, a brown bird with much the habits of our nuthatches, but much larger. Together with the woodhewers you find the handsome Bonaparte's woodpecker, which also has a harsh and rattling cry. The cry of these woodpeckers is so disagreeable as soon to become annoying. You can not escape them, as they are especially fond of building their nests high up in the cocoanut palms near houses. The woodhewer is more considerate, as it nests mostly in the cactus trees.

Here in the scrub you find the spine-tails, small birds with habits like ground sparrows, and the tawny cuckoo, the only American cuckoo known regularly to lay its eggs in the nests of other birds, generally victimizing spine-tails. Here also are the beautiful honey creepers, the brilliant cardinals, much the same as ours in color and in habits, the ground doves, the pygmy owls, queer little miniatures of owls, various kinds of exquisite hummingbirds, and flycatchers, gnat-catchers, mockingbirds, and some birds of other types, like martins, nighthawks and goatsuckers.

In the deep forests on the mountain slopes above El Valle the yellow-headed parrots are the most conspicuous birds. But they are only conspicuous when on the wing. In the trees they are very difficult to see owing to their green color and their adroitness at concealing themselves. You sometimes come upon a tree with a flock of parrots in it. You do not suspect their presence until suddenly they go screeching off over the tree tops. They are powerful fliers, and you often see them high in air. When flying they seem to lack both head and tail and to consist merely of two moving wings. The natives call them "loro" from their cry. There is another kind of parrot, the so-called Amazon, in these forests also.

In the still mountain woods you sometimes hear a distant cawing, and you at once suspect a crow. But the distant cawing really comes from near at hand and is the cry of the barred ant-shrike, a small black and white bird which sits up very straight and in this, as well as in its long crest, resembles our cedar waxwing.

Of all the feathered tribe on Margarita the lance-tailed manikin seemed to me to be the most pleasing and generally attractive. This little bird is dark brown, with a large patch of light blue on the back and a bright red topknot. Its clear whistle is a distinctive feature of the mountain forests. The natives call it "tintoro" from its cry.

Living only in the forest are a number of other birds, like the yellow-billed thrush, the black and white tanager, a

vireo, the mountain dove and the curious guan.

There are in all about eighty different kinds of birds known from Margarita Island, and undoubtedly many more remain to be discovered.

One day when I was on the sandy plain near the coast my attention was attracted by a flock of about twenty very large birds flying in the form of a wedge in the direction of the lagoon which separates the two parts of the island. Their size and actions suggested geese, and it occurred to me that perhaps they were flamingos.

There was one great mystery connected with the birds of Margarita which I could not solve. Near the top of a high spur of the central mountain just south of El Valle there was a large cave consisting of a spacious chamber with an entrance about ten feet in diameter and two shafts, one leading directly up through the roof, and the other slanting upward. The whole floor of this cave was covered with the whitened skeletons of small birds and mammals, the larger part being those of the small doves. I recognized a skeleton of Bonaparte's woodpecker among them, and also the remains of a mouse opossum and of a small rodent. These skeletons must have been accumulating for very many years, as in some places they were an inch deep and the ground in front of the cave was strewn with them.

The question is, What could have brought them there? The cave was high above any place where these forms could be found commonly, if at all, and no birds but vultures were seen in the vicinity. There was no evidence that any owls had ever lived inside the cave. Numbers of small bats were the only living creatures there. These were of several different kinds, but none of these kinds has ever been known to carry warm-blooded creatures. When they attack them they merely bite a hole in them and suck the blood; but most of the bats were insect eaters.

So far no one has been able to explain this mystery.

SCIENCE AND GOOD WILL IN THE PACIFIC

By Professor T. D. A. COCKERELL

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While Europe wrangles and America hesitates, the Pacific, as befits its name, stages a living drama of peace. When first invited to attend the Pan-Pacific Food Conservation Conference at Honolulu, I hesitated, not being aware that every one does what Mr. Alexander Hume Ford asks him to do. It involved a long and expensive trip, and I was not at all sure that when I got there I should not find a conference resembling many which have been held elsewhere. It would, no doubt, be amicable on the surface, and the entertainment afforded would certainly be lavish. But should we not see a number of national groups or cliques pulling against each other, seeking advantages and doing as little as possible for the common good? Even my good friend, Dr. L. O. Howard, the U. S. entomologist, who presided, confessed to me that he was not without certain misgivings. But in his mind, as I think in the minds of all present, doubts were dissipated, and we realized with enthusiasm that genuine international cooperation had been achieved. This does not mean that there were no differences of opinion, nor that controversial subjects were avoided. So far as possible, within the scope of the purposes of the meeting, every pertinent matter was freely and openly discussed, and there was no disposition to minimize the difficulties inherent in dealing with the food supply of the peoples of the Pacific area. It is probably no exaggeration to say that the feeling among the delegates was, at the close of the meetings, that a way had been found to mobilize the forces of science and good will in such a manner as to justify, in a troubled world, reasonable hope of permanent peace and prosperity.

When we ask how this was accomplished, certain facts stand out in bold relief. The first of these is Mr. A. H. Ford. When he came to Honolulu he was concerned in organizing the Outrigger Club and the Trail and Mountain Club, two of the most useful and vigorous local organizations. But having larger visions, and perceiving that Honolulu was at the cross-roads of the Pacific, he developed the Pan-Pacific Union, a sort of unofficial League of Nations for the Pacific area. The idea readily took root in the cosmopolitan and progressive atmosphere of the Hawaiian Islands, and secured the support of prominent persons in numerous countries. Every week the available members assembled at luncheon in the Young Hotel, and interesting people visiting the islands were always invited and brought in touch with the movement. It was a matter of fundamental importance, decided at the beginning, that the Union should be wholly "unofficial" and "non-political." It combined the spirit of science with that of religion, if we mean by these terms the search for wisdom and the service of mankind. Superficial people argue that such a body has no real power, neither laws nor armed forces to support its decisions. But laws and armed forces do not of themselves carry conviction or promote friendship. The way to get international cooperation is to cooperate, and this is only possible in a spirit of amity. Furthermore, all solutions for our problems depend on wisdom, which is the product of organized knowledge. Such wisdom may come

from any quarter, and science cares nothing for official sanctions. In the spirit of science, discussion is free, and each man desires to impart what he knows instead of concealing it from motives of "policy."

Thus organized, the Pan-Pacific Union became sponsor for great international gatherings. Mr. Ford insists that the Union does not hold these meetings, it merely calls them together and then they hold themselves. If the distinction seems too subtle, it is at least part of the plan to permit perfect freedom, and avoid in every respect even the appearance of undue domination. Professor Wm. E. Ritter[1] has given an excellent account of the Australian meeting, showing how seriously it was taken in Australia, and what great efforts were made for its success. Each conference is able to profit by the experience of previous ones, and has at its service the good will these have created. Thus year by year we may expect greater success and more beneficial consequences.

In spite of Mr. Ford's desire to avoid domination, he has felt obliged to make one condition which is absolutely fundamental. The various governments and institutions are invited to send delegates or representatives, but these are to be of a certain type. They must be scientific experts, or those who may be trusted to act in a scientific spirit.[2] The professional politician, who regards politics as a game for advantage or supremacy, is not wanted; neither is it desired to see "worthy" persons needing a holiday at the public expense. We should all, so far as possible, cooperate in the effort to keep out these undesirables, who would, if present in force, defeat the purposes of the gatherings. On the other hand, men of the right type, if active in political life, are the more welcome. Sir Joseph Carruthers, former Premier of New South Wales, and the Hon. G. M. Thomson, member of the Legislative Council of New Zealand, were among the most serviceable members of the convention. The latter is, indeed, also well known as a zoologist.[3] Perhaps we may say that one of the major services of these meetings is to recognize and encourage the scientific spirit in public affairs, supporting those politicians who represent it and bringing the idea to the notice of those who do not. The problems dealt with by the Food Conservation Conference were very extensive. It might create surprise that Dr. L. O. Howard, an entomologist, should be chosen as the presiding officer. To those who know him this choice is natural enough on account of his personal qualities, which make him an ideal chairman. But actually the entomology had a good deal to do with it. In the Pacific region there is hardly any subject of greater practical importance. As we listened to the discussions by representatives of the sugar-cane industry, gathered together from Cuba, Queensland, Fiji, Java, Formosa and elsewhere, it was perfectly evident that pests affecting cane in different regions, if brought to-

[1] *Science*, March 28, 1924.

[2] Those present at Honolulu (1924) included E. W. Allen, C. L. Alsberg, E. W. Brandes, Mario Calvino (Cuba), F. D. Fromme, J. Arthur Harris, W. B. Herms, W. E. Hoffman, D. S. Jordan, Kamakishi Kishinouye, Armand Krempf, S. F. Light, Sun Lin (China), C. L. Marlatt, Rokuichiro Matsujima, E. D. Merrill, E. Mitsui (Korea), H. L. Montalban, Herbert Osborn, Kintaro Oshima (Formosa), R. L. Pendleton, W. T. Pope, R. J. Rodrigues (Macao), H. N. Savage, Josephine E. Tilden, Lien-Teh Wu (Peking), V. R. H. Zwaluwenburg (Mexico), in addition to those mentioned in the body of the article, and many others, including of course the group of well-known scientific men resident in Honolulu. A very valuable member was Dr. Koliang Yih, Chinese Consul General at San Francisco.

[3] I had long known the name of Thomson in connection with the discovery and description of the extraordinary archaic crustacean *Anaspides*, and it was a great pleasure to hear from him the details of its occurrence in the mountains of Tasmania. Since returning I have received from Mr. Thomson a lengthy memorandum on the conference, reporting resolutions, etc., submitted by him to the New Zealand Parliament, and printed by order.

gether, would make the production of cane impossible. The Hawaiian Islands had already had some very severe and costly lessons in sugar-cane entomology, and relief had been found through the introduction of natural enemies from remote regions whence the pests originally come or where their close relatives were native. The Hawaiian Sugar Planters Association maintains a research laboratory, which has produced much valuable scientific work, and the government has at the wharf a Plant Quarantine Station, which has experts and appliances to prevent, so far as humanly possible, the landing of additional pests. So far as they go, these arrangements are all to the good, and it is certainly due to them that sugar cane is to-day a flourishing and profitable crop in the islands. Yet much more is necessary before we can be reasonably safe. On the side of quarantine, we want approximately uniform regulations in all countries we have to deal with, and especially adequate control of exports. It is almost incredible, to those who are not familiar with the details, how many dangerous pests, especially scale-insects, arrive at American ports every month. With all the vigilance possible it is hard to prevent the spread of pests which are continually and carelessly sent abroad. International cooperation is necessary if we are to be saved from calamity. In spite of all we were able to do, several first class pests, such as the camphor scale and the so-called Japanese beetle, have recently obtained a foothold in the United States and are costing us large sums to deal with. During the meetings an interesting illustration of the distribution of scale insects came to light. The Chinese community gave a banquet to the delegates, and the tables were prettily decorated with green branches and flowers. Miss Alice Eastwood, the well-known botanist of California, who sat next to me, called my attention to some sprigs of *Aglaia odorata* which were infested by a white scale. I secured specimens and sent them to the U. S. Bureau of Entomology and the British Museum. Mr. Frederick Laing, of the latter institution, at once wrote me that they were *Aulacaspis fulleri*, a scale I had myself described from South Africa many years ago, and which had not been reported from any other region. It may have been in the Hawaiian Islands a considerable time, as it seems not to be very destructive. It is impossible to say in advance what insects will become major pests in a new country. Accidentally introduced without their natural enemies, they often spread almost unchecked, and any species of insect would soon overrun the whole world were there no obstacle to its multiplication. Thus we need to know the potential pests of all countries. For example, if a particular kind of insect is destructive, its near relatives are to be suspected as possible sources of trouble. It thus becomes highly expedient to revise or monograph the whole group concerned. This does not mean simply to sit down in a museum and describe the available specimens, as these will doubtless include only a fraction of the existing species. It means exploration and collecting, and the cooperation of entomologists in many countries. It means also proper facilities for publication. When a recently introduced insect gains a foothold, it is often out of the question to get rid of it entirely by poisons or gases or mechanical means. The sum of $20,000 appropriated to fight the camphor scale (*Pseudaonidia duplex*) in Louisiana did not prevent it from spreading into the wild country, where it is practically impossible to reach it. In such cases entomologists seek out appropriate natural enemies, which will pursue the pests everywhere, and while probably not exterminating them, will keep them in check. Where may those enemies be found? It is not always easy to say, sometimes a chance hint or record has

given a clue to their whereabouts. But it took Dr. Muir, who has a positive genius for this sort of work, some years to find the appropriate enemy for the beetle larva that was destroying the cane in the Hawaiian Islands. Not only may the desired discovery be long delayed, the crops suffering in the meanwhile, but it may never be made. Certainly it would not have been made in the case just mentioned had not Dr. Muir been extraordinarily persevering and sagacious, and the Sugar Planters' Association ready to back him up for a long period. Such a combination could not be expected to occur very often. But such work ought not to be thus haphazard. It ought to be aided and made relatively simple by a comprehensive knowledge of the enemies of injurious insects in all the countries bordering on the Pacific and all the islands of that ocean. This again means exploration and cooperation and publication. It accordingly appears that there is a very large entomological program arising out of the deliberations of the Food Conservation Conference. So large, in fact, that it will not be carried out in our generation; but fortunately it can be developed as rapidly or slowly as circumstances permit; every advance, no matter how small, being of some value.

Were it possible to establish barriers around the several countries, prohibiting commerce or travel, many dangers and difficulties might be obviated. No one advocates such a program to-day, nor indeed is it in any sense practicable. Furthermore, under such conditions the populations would be subject to periodical famine unless they were kept down to the numbers capable of being supported during poor years, perhaps with the aid of some accumulations from better times. Histories of antiquity are full of descriptions of such conditions, but to-day we hope to overcome famine through science and international cooperation. Commerce, so long as it is free, acts as a sort of insurance, because shortage will not occur everywhere at once. With international trade, under the continually improving conditions of transportation, the world can safely maintain a population many times greater than was formerly possible. This is only desirable if the people can be reasonably guaranteed those things which make life tolerable, and especially freedom from acute shortage of food. Unless we can definitely abandon the old methods of oppression and war, and all the burdens they impose even in times of peace, and substitute international commerce and intercourse, it is proper to advocate at once a considerable reduction in the numbers of mankind. Dr. P. J. S. Cramer, delegate from Java, put the matter graphically in telling me about his island. Rice is of course the staple food of the Javanese. But rice can not be grown except in the lowlands, and the population of Java now considerably exceeds that which can be supported on the local rice. This is no hardship because rubber, coffee and other products can be grown on the slopes and hills, and these find a good market, so that money is obtained to purchase more rice from elsewhere. But suppose the countries now exporting rice find they have not enough, or suppose something happens to rubber or coffee. Then there at once arises a serious, if not critical, situation. It may be met if conditions are fully understood in advance, but in the absence of proper knowledge, which also involves cooperation, disaster may be unavoidable.[4]

Another illustration of the necessity for international action was afforded by

[4] I was much interested, when on the way to Japan in 1923, to meet Viscount Akiro Toki, of the Japanese Department of Agriculture and Commerce, and to learn that he was returning from a mission to Europe, for the purpose of learning the best ways of baking bread and utilizing wheat as food. This is a good example of practical forethought in national administration.

the discussion of the locust problem, introduced by a paper sent by Professor C. F. Baker from the Philippines. As is well known, invasions of destructive locusts are the most terrifying manifestations of insect activity. In a few hours they reduce a prosperous region to a barren wilderness. Yet they can be dealt with if taken at the source and destroyed when young in the vicinity of their breeding places. These breeding places are usually far from the regions likely to be devastated and probably in some other country. They may well be in sparsely populated regions, which have not the means, had they the will, to destroy the little locusts. The only way out is again through cooperation, guided by the advice of expert entomologists, who must explore all the territory involved. Such examples may be multiplied almost indefinitely, showing that modern countries can not live by themselves, nor can they exist without utilizing scientific knowledge. Those who fancy that what was good enough for our ancestors ought to be good enough for us should remember, first, that we are enormously more numerous than those ancestors; and, second, that while modern transportation is necessary in the modern world, it creates new difficulties of the most serious character which must be overcome.

One of the difficulties, quite unrelated to entomology, was brought before the conference by Dr. B. W. Evermann. He described the fearful destruction of birds and marine life, and the pollution of beaches, by oil thrown out from vessels. It is a world-wide evil; I have noticed the effects on the coast of England. It appears that methods can be adopted to prevent the spreading of oil on the sea, but only international agreement will compel shipping to conform. Individual countries are relatively helpless, but the need for action is so great that it surely will not be long delayed.

The resolutions passed by the conference were framed in the several sections and then presented in open meeting. They number thirty-three, of which the following are perhaps most significant:

IV. Among other things, strongly supports the plan for a Pan-Pacific Information Bureau that may have branches in various cities and collect and distribute accurate information about all the countries about the Pacific.

VII. Asks the Pan-Pacific Union to form a committee of men versed in International Law to form a Pan-Pacific Bar Association, in order that legal advice may be available in framing international agreements.

VIII. Commends the action of Messrs. George and William Castle in offering a home for the proposed Pan-Pacific Research Institute, and urges support for the project. The fine house and grounds given by the Messrs. Castle are in the Manoa Valley, and were visited by the delegates during the conference. The project is going forward with the cooperation of distinguished scientific workers, and bids fair to develop into something of first-class importance. It is to be strictly Pan-Pacific, that is, international.

IX. Recommends uniform weights and measures, preferring the metric system.

X. Asks that important scientific and technical publications, in the Pacific area, when not published in English, shall present English abstracts.

XII. Urges support for international scientific abstracts.

XVIII. Advocates international control to prevent pollution of the sea.

XX. Urges steps for the protection of sea turtles. XXI similarly deals with marine mammals.

XXIII. Asks support for the study of the marine life of the Pacific.

XXIV. For an International Crop Protection Committee, dealing mainly with insect and fungus pests.

XXV. Refers to the important results obtained by the use of the natural enemies of insect pests, and urges the training of men capable of working in this field, and the establishment of permanent stations for entomological and phytopathological investigations.

XXVI. Supporting general biological investigations throughout the Pacific.

XXVII. Deals with the locust problem.

XXVIII. Urges uniformity of quarantine regarding live stock, to be obtained through a joint commission.

XXIX. Calls attention to the importance of exact information concerning the conditions and possibilities of rice-growing.

XXX. Relates to soil surveys.

XXXI. Recommends official (uniform) grades and standards for rice, present practices being misleading and confusing. XXXIII has to do with the general problem of uniform commercial standards.

XXXII. Asks nations to publish crop forecasts and statistics of food production and consumption, in order to stabilize and guide the actions of all countries.

It will readily be seen that we have, growing out of the brief sessions of the conference, a comprehensive program for social advancement and for the abatement of many evils. No one expects to see all this realized in the near future, but for representative men to meet and agree, and carry home the message of inspiration and hope, is at least a matter of some consequence. All reforms and advances have some small beginning, and although others will doubtless receive credit for carrying out various portions of the above program, the work of the Food Conservation Conference will probably appear more significant in the pages of history than it does at the present time.

Various arrangements were made to emphasize the international character of the gathering. The flag ceremony, when the Governor of Hawaii stood on the steps of the Iolani Palace and received the flags of all nations and states represented, was a beautiful and inspiring affair. United States Infantry and marines formed a guard of honor on each side of the driveway, and the U. S. flag was dipped as the others went by. The bearers of the flags were suitably dressed young women or boys, making the ceremony as interesting and attractive as possible. There was a large crowd, and Governor Farrington was surrounded by the most distinguished people then in the island.

During the conference the various communities in the island gave banquets or other entertainments for the delegates. Thus we were received by the Hawaiians, Japanese, Chinese, Koreans and Filipinos. Although these various racial types keep distinct in the islands, they are taking advantage of the conditions created by the Americans and appear to get along together surprisingly well. In this respect the Hawaiian Islands perhaps bid fair to duplicate the conditions in Switzerland. The political problem at the present time is a complex and difficult one, and I did not attempt to study it with any care.[5] It seems to be recognized that there will be a greater development of practical democracy, and that the Hawaiian-born Japanese, growing up, will have an increasingly large part in public affairs. Making all possible allowance for criticisms, it seems that on the whole the islands present a most striking and hopeful experiment in racial cooperation. If administered in the spirit of the Pan-Pacific Union, they should go forward to a very happy future.

At the close of the meetings there was held a farewell banquet, at which short speeches were made by representatives of the various nations. Although we refuse to recognize Russia politically, Siberia is in good standing with the Pan-Pacific Union by virtue of its place on the Pacific. No actual delegate from that country being present, I was asked to speak on behalf of Siberia, which I did with pleasure. At the next conference there will doubtless be Siberian delegates.

The next conference, to be known as the Third Pan-Pacific Science Congress, will be held in Japan in the autumn of 1926. It may be, and must be, a tremendous influence for good. Let us support it in every way, and with the cooperation of the Japanese, do our part to permanently establish peace and good will as the rule of the Pacific.

[5] I was present at a demonstration of Filipino sugar-cane laborers at Hilo, Hawaii. They were striking for better conditions and I learned that there was widespread discontent. Yet in Kauai I was surprised to see the evidences of general prosperity, as shown by the appearance of the people, their homes, their many automobiles, etc.

RADIO TALKS ON SCIENCE[1]

THE PRESENT PREVALENCE OF CERTAIN DISEASES

By Dr. VICTOR C. VAUGHAN

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MEASLES is now unusually prevalent in all parts of the world. It is highly desirable that this disease should be recognized in the preeruptive stage. Uncomplicated measles is not highly fatal, but it predisposes to a form of pneumonia which is highly fatal. When there is adequate medical inspection, it is best not to close the schools on account of an epidemic of measles, but all children should be inspected daily. A skilled physician is able to detect measles, in the majority of instances, in the preeruptive stage; then the child should be isolated, kept in bed, and the younger children exposed, especially those under one year of age, should be treated with the serum of a convalescent. Strict isolation, even from other cases of measles, is required. When many cases of measles are kept in the same room or ward, one may carry a virulent pneumonia organism and may transmit it to others. One attack of measles gives lasting immunity. Adults who have never had the disease are as susceptible to it as children. In the treatment of measles life depends largely upon the prevention of the development of pneumonia.

Influenza has shown a tendency to increase in frequency and virulence during the past two or three months; this is evident in both hemispheres. However, no great pandemic of this disease is probable at the present time. The increase will continue with variations until warmer weather comes. The cause of influenza has not been definitely ascertained; there is no vaccine and no specific treatment. Unlike measles, one attack of influenza does not confer lasting immunity. Success in the treatment of this disease depends upon early recognition, isolation and rest in bed. Special attention should be given to the sterilization of tableware, cups, knives, forks, spoons, etc. "Hand to mouth infection" is recognized as an important factor in the distribution of the disease. Uncomplicated influenza is not a deadly disease, but, like measles, it predisposes to a highly virulent pneumonia. Influenza comes in waves and is most severe in cold weather, although it may be highly fatal at other seasons. Judging by the past, a pandemic of this disease will come sooner or later. There is, however, at present no basis for a prediction as to when this will come. At present every bad cold should be suspected and the victim should isolate himself and keep in bed.

Scarlet fever has not shown any increase in virulence for some years past and continues, for the most part, to be of the mild type. In 1924 an antitoxin for this disease was discovered and its value has been tested since that time. There are three stages in the development of scarlet fever: in the first, the organism grows superficially and produces its poison, which is absorbed; in

[1] Broadcast from Station WCAP, Washington, D. C., under the auspices of the National Research Council and Science Service and the direction of W. E. Tisdale.

the second stage, the germ penetrates the tissue and continues the production of its poison; in the third stage, other germs, as well as the specific one, have penetrated the tissue and are elaborating their own poisons. The antitoxin is of great value in the first stage, acting almost with certainty in arresting the disease. It is of less value in the second stage and of but little worth in the third stage. Here, as in most infectious diseases, early recognition and prompt treatment are the factors upon which reliance must be placed. When we remember the disasters in the loss of speech and hearing, which so often follow scarlet fever, we should regard it as a most serious disease.

Smallpox is of two forms, mild and grave, and each is inclined to breed true. The virus of this disease has not been clearly identified. There is, however, a vaccine which, when properly used, guarantees protection. The one vaccine protects against both kinds of smallpox and the protection secured by vaccination and revaccination is even greater than that induced by one attack of the disease. Smallpox prevails where and when vaccination is neglected. When vaccination is compulsory and is strictly enforced, there is no smallpox. There were nearly ten times as many cases of smallpox in the United States in 1925 as there were in Russia. In most continental European countries in 1925 there were no cases of this disease. In England, where vaccination was discovered, there were, in 1925, about two hundred cases, while in twenty-seven states in our own country there were, during the four weeks ending December 26, 1925, 1,326 cases, while in the whole of Russia during the same time there were not more than 150 cases.

Poliomyelitis, or infantile paralysis, has been on the increase in this country each summer for the past three years, and unless something is done to prevent it, we are going to have marked epidemics of this disease. For the seven weeks ending July 18, 1925, thirty-two states reported 462 cases, while for the year before, during the same time and in the same states, there were 121 cases. During the first half of the year 1925, California reported 154 cases; New York, 66; Minnesota, 46; New Jersey, 35, and Illinois, 20. Besides these there were sharp outbreaks in South Carolina in April, 1925, and the same occurred in Louisville, Kentucky, and adjoining cities later in that year. We are still quite ignorant of the cause of this disease and how it is disseminated. Experts should be sent wherever infantile paralysis is reported and thorough investigations should be made.

Asiatic cholera was not reported in the Western Hemisphere in 1925, but there were outbreaks of this disease at maritime ports in China, Siam, Japan and the Philippine Islands. By the close of the year all these, with the exception of those in Siam, had been eradicated. In India, where cholera is endemic, the number of deaths from this disease in 1925 was about one half of what they were in 1924. During 1925 this disease was entirely absent from the central provinces and from the city of Bombay. Cholera has been entirely suppressed along the Volga and throughout Russia. At the close of the year 1925 there were still cases in Calcutta, Madras and Bangkok.

Typhoid fever decreased in all European countries during 1925, but increased slightly in the United States. This increase was partly due to shellfish infection, but there were water-borne outbreaks also. The people of this country, including health officials, seem to think that we are practically done with typhoid fever. In my opinion, this is not the case. We depend largely upon chlorination for the destruction of the typhoid bacillus in our drinking water, but there is a limit beyond which this can not be carried. Typhoid vaccination

of civilian population has been practised in North Carolina with success.

Typhus fever, which is spread through the agency of body lice, has rapidly receded in Russia, Poland and Czechoslovakia. Not only are the cases less numerous, but the types seem to be milder. This indicates that the people in the regions mentioned are giving more attention to personal hygiene and are freeing themselves from vermin.

Yellow fever is apparently extinct in the Western Hemisphere. There has been no yellow fever in Central America since October 22, 1923, when a small outbreak appeared in Salvador. All other countries from Mexico to Chile have been free from this disease for a much longer period of time. Turning to Brazil, there have been no cases in the large cities for two years, and the last case reported in a village back of Bahia was seen by Dr. Joseph White, expert for the International Health Board, and pronounced by him not yellow fever. Omitting this one, the last death reported from yellow fever in the Western Hemisphere occurred in May, 1925. Before the Panama Canal was completed, epidemiologists expressed fear that yellow fever might be transmitted from Central or Western South America to the Orient, but this danger has been wholly removed by the eradication of the disease from these regions. Yellow fever has been reported, and is still being reported, along the west coast of Africa. The International Health Board has sent a commission to investigate this matter and this commission arrived at Lagos, Nigeria, in June, 1925. The purpose is to determine whether the disease reported is yellow fever, and, if it is, to stamp it out. If it be found that yellow fever is actually endemic in Nigeria, its elimination will be a problem of world-wide importance. Railroads have been planned and in part have been built over the high plateau of Central Africa, and a disease prevalent in Nigeria may easily reach the east coast and from thence take passage to the Orient, where the Stegomyia (the mosquito involved) in great numbers awaits its coming and will not delay in its transmission.

Human plague was reported during 1925 in only two ports in the Western Hemisphere—one on the west coast of South America at Guayaquil and the other on the east coast at Bahia. In both of these localities strenuous efforts are being made to exterminate the rats, which are the harbingers of the flea which transmits this disease. In India there has been less plague than during any year since 1899. There have been a few cases in Mediterranean ports, one at Beirut and one at Patras. Early in the year there were a few cases in Egypt, but there have been none during recent months. People all over the world are apparently making strenuous efforts in their contest with rats.

It will be understood that rat plague is much more widely distributed than human.

Tuberculosis shows a gradual decline over the greater part of the world. There has been no noteworthy discovery in the treatment of this disease. Late in 1924 a Dane announced a cure, but he has not been able to substantiate his claim.

Malaria is gradually receding in this country towards the Gulf of Mexico. Forty years ago the malarial belt extended to the Great Lakes and protruded over large areas in the New England States. This recession is due largely to the reclamation of drainage of land for agricultural purposes, thus eradicating the breeding places of the Anopheles mosquito. At first this was due solely to economic interests and its value as a health measure was first appreciated about twenty years ago. The prophylactic employment of quinine, of screens and of mosquito exterminators, such as small fish, is now recognized. In nearly every part of the world antimalarial

measures, largely influenced and directed by the International Health Board, are in operation. We can optimistically look forward to the time, if science meets with no setback, when the tropics, containing the most productive areas of the world, will become the great seat of civilization. The malarial belt in Russia is rapidly receding. Soon after the war it reached Archangel, the highest point north ever known to have been reached by this disease. Malaria is still more or less prevalent along the Volga, but is gradually receding southward. There are spots in Russia where the prevalence of this disease continues to be high, but even the Soviet government seems to be appreciative of health measures.

Hookworm infestation is also gradually receding again under the influence and operation of agencies supplied by the International Health Board. Even the inhabitants of Central America and those of the South Sea Islands are building model latrines.

Encephalitis lethargica, ordinarily known in this country as sleeping sickness, but quite distinct from the sleeping sickness of Africa, has apparently revealed its causal agent to the researches of Miss Evans, of the United States Hygienic Laboratory, and Dr. Freeman, of St. Elizabeth's Hospital. As early as 1917 a doctor in Vienna found in the brain of a patient who died from this disease a micrococcus, but, of course, whatever this doctor might believe, he could not claim that he had discovered the causative organism, since he had found it in only one case. Miss Evans and Dr. Freeman state that they have succeeded in inoculating rabbits with this organism and transmitting the disease through a series of fourteen animals. They state that their find appears like a common streptococcus.

Dengue, a most distressing but not highly fatal disease, widely prevalent in tropical and semi-tropical countries, is distributed by a mosquito. This was demonstrated many years ago by an American physician, Dr. Graham, then a teacher in the medical school at Beirut, Syria. However, Dr. Graham was not sure about the species of mosquito which he employed in his experiments. Recently this has been determined by a board of medical officers working in the Philippines and they find that dengue is transmitted by the Stegomyia, the same mosquito which distributes yellow fever, and not by Anopheles, the malarial mosquito, nor by the Culex.

Leprosy, now well provided for at the National Leprosarium at Carrville, Louisiana, continues to supply sporadic cases —thirty-six in 1924 and thirty-eight in 1925.

Cancer, so far as treatment is concerned, still lies in the hands of the surgeon, and those who have any suspicious growth should immediately consult him.

Goiter, certain forms at least, as was shown a few years ago, is due to the absence of iodin in our food, drink and the air which we breathe. As soon as this was demonstrated, the food manufacturer, ever ready to glean the coin which may be gained by the application of scientific discoveries, got busy and, among other things, flooded the market with iodized salt. This is already doing harm. It should be understood that there are different kinds of goiter and all kinds are not prevented, or, being present, are not benefited by medication with iodin. Moreover, it should be understood that the dosage of iodin in the prevention or in the treatment of goiter is in milligrams and not in grains, and that there are sixty-four milligrams in one grain. The maximum dose of iodin in the prevention or treatment of goiter should be ten milligrams or about one sixth of a grain daily for not longer than one month. The wholesale use of medicine of any kind or chemicals of any kind by the people without medical supervision is fraught with danger.

In my opinion, the time has come when

epidemics may be predicted with as much certainty and at no greater cost than the weather is now forecast, and, what is more important, when epidemics are foreseen, they may be prevented, and this does not apply to the weather. The newspaper of the future will carry on its front page a condensed health report much as it now carries a similar weather report.

NEW RIGID AIRSHIPS

By STARR TRUSCOTT
BUREAU OF AERONAUTICS, NAVY DEPARTMENT

THE House Committee on Naval Affairs recently recommended to Congress the construction of two large rigid airships.

The proposed airships are to be of six million cubic feet capacity. This is about three times the volume of the *Shenandoah,* but the length will be only about 15 per cent. greater, and the diameter about 50 per cent. greater. The intention is to provide the best ship which can be built at the present time. The authority recommended is in line with the old-established naval policy which calls for quality first and quantity second. It will not give a large number of airships, but it will give two very *good* ships.

The Navy began to study rigid airships intensively in 1917. Then this country had practically no knowledge of the science of rigid airship design or of the materials and art of construction. Once begun, study and experiment have never stopped. Everything that could be learned from others has been obtained. The *Los Angeles,* a ship of the best and latest design, has been obtained from the German firm which built more than one hundred successful airships. The best design, construction and operating personnel of that concern have been brought to this country and are now available for aiding in the further development of rigid airships in the United States.

No other nation has so intensively continued the study of the various parts of the rigid airship problem or has done so much work on them. We now have more information regarding rigid airships at our disposal than any other nation. The action of the committee was, therefore, peculiarly timely.

I am not going to describe a rigid airship, but I want to recall to you that a rigid airship has a rigid structure for maintaining its form and sustaining the various loads impressed upon the ship as a whole. The gas is contained in a number of independent cells and the airship usually has several sets of propellers and engines.

The principal things which we must know—and have—to design and build a successful rigid airship are:

(1) The airpressure—or aerodynamic—loads on the ship as a whole while in flight.

(2) How the aerodynamic and weight loads are distributed in detail to the individual members of the structure.

(3) Satisfactory materials from which to make the members of the structure.

(4) Satisfactory materials from which to make the gas cells to contain the buoyant gas.

(5) Engines which have sufficient power combined with lightness and extreme reliability.

There are many other things, of course, but these are the most important.

The influence of the form of the airship and of the fins and rudders on its resistance to passage through the air and on the loads sustained by the ship is important, and a great deal has been learned from experience and research. Part of this has come from the wind

tunnel where small models of the airship —reproducing the full sized ship as completely as the scale will permit—are suspended in such a manner that the observers can determine not only the resistance to being driven through the air —or drag—but also how effective the fins and rudders will be in keeping the ship on her course. In the wind tunnel the model is held stationary by the indicating mechanism and the air moves by it, just reversing the condition with the real ship. Before a particular form is adopted it is tested in the wind tunnel in comparison with other forms.

Once the form of the hull and the position and size of fins and rudders has been decided we can begin to estimate the loads it will encounter in the air. This is possibly the most difficult problem of all.

Nearly every one has at some time walked or ridden across one of the old wooden covered bridges which may still be found in some sections. These bridges were usually built by bridge carpenters. The loads in the various members of these bridges were not accurately known or determined, but the size of timber or iron was determined by the success or failure of previous bridges, and this information was handed down from father to son.

When you ride over a modern bridge in your automobile or on a train the load which you and your vehicle throw into each piece of the structure—steel or concrete as the case may be—can be determined very exactly by the designer.

A few years ago the design of the structure of rigid airships might have been said to be in the old covered bridge period. To-day we have arrived at the steel and concrete bridge period.

The loads from the weight of the structure of the ship itself and from passengers, fuel and cargo are fairly easy to determine. Those imposed by motion through the air are not so easy.

A few years ago we could only reason that if a certain airship, whose design was known to us, had flown and withstood successfully certain combinations of speeds and maneuvers with certain cargo loads, another somewhat similar system of speeds, maneuvers and cargo loads—stepped up according to the size —could be used in the design of a new airship.

Recently we have gotten away from this method. One of the first steps was to measure the actual air loads at various points over the surface of an airship, including the surfaces of the fins and rudders. The first comprehensive test of this sort was made by the National Advisory Committee for Aeronautics on the Navy non-rigid airship C–7 a few years ago. The airship became a flying research laboratory, and the scientists taking observations flew day after day to get the readings required. Unfortunately this ship was not so large or fast as was desired and the results—while helpful—were primarily of value in telling just what points should be investigated in detail on a large rigid airship. Accordingly a similar and more extensive program will be carried out on the *Los Angeles*, and she is now being fitted with the necessary apparatus. Next month the *Los Angeles* will begin a series of maneuvers intended to duplicate everything that may be expected of her in actual service. She will be flown at various speeds and made to turn from her course with varying degrees of suddenness. She will be flown inclined upward by the bow and downward by the bow and swung around in circles. To describe the program in detail would be wearying. What is important is that throughout each maneuver the observers will make records at regular intervals showing exactly what the air pressures—and consequent air loads—are over the body of the ship and the fins and rudders. While these air pressures are being determined there will also be de-

termined the actual loads which the air pressure loads on the ship as a whole are producing in the principal members of the structure of the ship.

This far-sighted policy of the Navy in using the *Los Angeles* as a laboratory for obtaining scientific data for the design of larger airships and for the training of personnel, is certainly to be commended. The information and data obtained from the tests made on the U. S. S. *Los Angeles* will be most valuable, in fact indispensable, in developing the new design. No country in the world has as yet built and completed an airship of six million cubic feet capacity, although England is building two of five million cubic feet capacity each.

There are several theoretical methods which can be used to estimate the individual loads in the various girders and wires of a rigid airship. Five years ago the best theoretical methods available gave results so far apart that it was difficult to select which should be used. Since then we have improved our theoretical methods and have developed accurate and practical checks against them. One check is to measure the loads carried in the various girders and wires while the ship is actually in flight, as will be done on the *Los Angeles* in connection with the pressure distribution tests.

Another method uses a large model in which the girders of the full-sized ship are represented by bars of celluloid and the wires by fine steel wires. This model is loaded by weights applied to simulate the loads of actual service. The members take up and distribute their loads like the girders of a full-sized ship. This distribution is determined by actually measuring them in each member. These measurements are truly scientific measurements made by using methods originally developed by the scientist for other purposes. By using such a model an airship structure of a new type can be tested, and the best arrangement of parts determined, at a very moderate expense.

Scientific research has given us several materials from which to build the girders of our new ships. Probably duralumin, the alloy of aluminum, copper, magnesium and silicon which was used in the *Shenandoah* and *Los Angeles*, is the most practical at present. It has about one third the weight and about the same strength as structural steel. This gives parts having good thicknesses and in which substantial riveted joints can be made.

There has recently been quite a to-do about the corrosion of this material. Corrosion is simply another name for rust. Every one knows that steel usually rusts, but it is not thought mysterious. Duralumin also rusts, but under the same conditions it rusts much more slowly than steel. In thin pieces even a little rust may be serious, but we have every reason to believe that before this year is out we will have demonstrated that it is possible to prevent even the slower rusting of duralumin by the same general methods as with steel.

For ships of even larger size than six million cubic feet capacity, we consider the use of the newly developed so-called "stainless steels." Most housewives know this material in the form of knives. It does not stain after use with certain fruits and vegetables and rusts very slowly. These steels can be made so much stronger than the ordinary ones that in large girders the advantage of duralumin may disappear. However, it surely will remain in smaller ones where duralumin for the same weight will be three times as thick, and much easier to work with.

During the construction of the *Shenandoah* 150 girders—exact copies of those on the ship—were tested to destruction at the Bureau of Standards. Girders for the new ships will be designed according to the information thus

obtained and will be similarly tested to prove their strength.

The gas cells of the *Shenandoah* and *Los Angeles* were made of goldbeater's skin fabric, consisting of a light but strong cotton cloth to which was cemented a layer of goldbeater's skin. These skins—one of the layers of a part of a stomach of the ox—are very costly. They measure at most only 15″ x 40″ and must be laid with 1″ overlaps all round. So the statement that 500,000 cattle died to supply the linings for the gas cells of the *Shenandoah* is probably not exaggerated.

Chemical research is now preparing sheets of synthetic films which are much cheaper than goldbeater's skins and promise to be not only as good for the retaining of gas but even better.

Helium, our inflation gas, is a triumph of the physicist and chemist. The natural gases from which it is extracted contain less than one per cent. of helium and to get the two and one half million cubic feet of helium required to inflate the *Los Angeles* the plant at Fort Worth must handle about three hundred million cubic feet of natural gas. Yet helium now costs us only three and one half cents a cubic foot. Only ten years ago it would have cost—if you could have persuaded some one to let you have that much—at least fifteen hundred dollars per cubic foot. The cost is being reduced by each new improvement in the processes.

Few people realize what a unique advantage has been given to us in the possession of this helium supply. Any one—after careful trial and study—can imitate and possibly improve on any of the products of our brain or shop, but so far no nation has found a supply of helium comparable to ours. With the danger of fire from the ignition of the inflation gas done away with, we can do many things that others can not do and thus, we hope, produce superior airships.

Every one has followed the wonderful success of our aircraft engines. Here chemist and physicist have joined hands to give great power with light weight and reliability. American aircraft engines are the finest built to-day.

Germany, Great Britain and the United States have all together and to date completed about 150 rigid airships. Most of these were very successful, although constructed without the aid of the much more accurate information which we now possess. If these earlier ships could operate successfully under those circumstances and without the use of helium you can see why the continued study which has been carried on for these past years by the Navy Department has placed us in a position to proceed with the design and construction of new rigid airships with full confidence in their success.

"SEEING" WITH X-RAYS

By Professor F. K. RICHTMYER

CORNELL UNIVERSITY

No scientific discovery in the last half century has had a wider application, in both pure and applied science, than have X-rays. By means of X-rays your dentist can decide which tooth to extract, rather than to extract several in order to find which one was ulcerated. The physician can see the break in the bone almost as clearly as if the bone were freed from the surrounding flesh. Further, he can study the development or arrestment of such diseases as tuberculosis and mastoiditis. He can investigate certain disorders in the digestive tract.

And indeed he finds in X-rays a tool which has revolutionized certain phases of diagnosis and treatment, and which, during the war alone, saved thousands of lives. The engineer uses X-rays to give him very valuable information with regard to the properties of materials which he uses in making bridges, automobiles, airplanes, filaments of incandescent lamps, electrical equipment and a thousand and one other things. By means of X-rays the crystallographer has vastly extended his knowledge of the way in which atoms are piled together to make up crystals, such as snowflakes, diamonds and ordinary table salt. And, most fascinating of all, the physicist has used X-rays to construct what one might, without too great a stretch of imagination, call a super-microscope, by means of which he can study the architectural make-up of the ultimate constituents of matter, *i.e.*, molecules and atoms. It may be interesting, therefore, to say a few words about the origin and development of this wonderful agency of modern science.

In the autumn of 1895 Wilhelm Conrad Röntgen, a German scientist, was experimenting in his laboratory with that very fascinating phenomenon, the passage of electricity through the rarefied gas in a partially evacuated glass tube. Accidentally and very unexpectedly he discovered that there proceeded from that part of the glass wall which was struck by the discharge an entirely new type of radiation which was like ordinary light, in that it travelled through the air in straight lines, affected a photographic plate and caused fluorescence; but which differed from ordinary light in that it could not be reflected by a mirror or refracted by a prism. And most surprising of all this new radiation was able to pass very easily through substances opaque to ordinary light, such as black paper, wood, thin sheets of metal, etc. Bones were more opaque than flesh, and hence cast a deeper shadow on the photographic plate, a circumstance which made possible the well-known X-ray picture. Röntgen made a guess that this new radiation was just like light, except that it was composed of much shorter wave lengths—just as the sound from the high notes of the piano are of shorter wave length than that from the low notes. Later investigations have shown that Röntgen was right. X-rays are light waves of very high frequency—approximately one thousand to ten thousand times that of ordinary light. (The highest note on your piano has a frequency approximately 150 times that of the lowest note.)

X-rays are produced in a highly evacuated tube, usually glass, by causing swiftly moving electrons coming from a heated filament such as you have in your radio tubes to be suddenly brought to rest by colliding with a solid body, such as platinum or tungsten, usually called the target. A simple analogy will illustrate the process. Imagine a tin pail full of bird-shot suspended from the ceiling of your room. Immediately beneath the pail put a tin pan bottom side up. Drill a small hole in the pail and allow a fine stream of shot to fall upon the pan. The sound which you hear—a mixture of two distinct parts, the characteristic note of the pan and a mere noise—is, in a rough way, the acoustical analog of a beam of X-rays. The pail corresponds to the filament, which when heated gives out electrons. These, in turn, correspond to the shot. The tin pan corresponds to the target of the X-ray tube. And the force of gravity pulling the shot downward corresponds to the electrical field which is applied between the target and the filament to accelerate the electrons so that they strike the target at high speed. A beam of X-rays, just as in the case of the sound from the tin pan, is composed of two parts, one which is characteristic of the material of the target, and the other which depends on how hard the electrons strike the target.

In scientific research, just as in exploration, an unexpected discovery proves of far greater value than the original quest. Columbus accidentally ran upon America in his search for a new route to the East Indies. Had Röntgen, in 1895, been seeking some device to assist the surgeon in setting broken bones, it is almost certain that neither he nor any one else would have thought of experimenting with electricity and evacuated tubes.

Indeed, so common are these unexpected things in science that one is inclined to question the general validity of the old saying, "necessity is the mother of invention." Sometimes, to be sure, it is true. It was not necessity, but rather scientific curiosity that urged Michael Faraday, a century ago, to experiment with electricity and magnetism, and thus to discover the fundamental principles which to-day make the electric motor and dynamo possible. Dynamos and motors became necessities long after Faraday's discoveries.

Accordingly one feels justified in saying that, valuable as are the applications of X-rays which are being made by the surgeon, the physician and the engineer, of still greater value, because of the fundamental discoveries which may grow out of them, are the experiments which the scientists are making with and by means of X-rays. You may be interested in some of the results.

After the radio program this evening sprinkle a few grains of table salt on a piece of black paper and examine them with a pocket magnifying glass. You will observe that many of the grains are little cubes, or, we might say, cubical crystals. The chemist tells us that this salt, which is such an indispensable article of our diet, is made up of atoms of two elementary substances or elements, sodium and chlorine, neither of which, alone, we should find very palatable. By a variety of physical and chemical methods the number of atoms in one of these crystals can be determined with high precision. Thus a cubical crystal of salt one centimeter (four tenths of an inch) on an edge, contains a number of sodium atoms which you can express by writing down the figures 224 followed by twenty ciphers; and an equal number of chlorine atoms. In spite of the fact that these atoms are very small—about a billion of them side by side would make a row an inch long—there are so many of them in one cubic centimeter of rock salt that if arranged in a single row, instead of in a cube, they would make a line twice as long as the diameter of the earth's orbit. Truly, an atom is far too small ever to be seen by the most powerful microscope.

But let me ask you a question: Did you ever see the wind blow? Of course he who has ever seen the snow fly or the branches of trees wave will say yes. Now you didn't actually *see* the wind, for it is invisible. You really saw the effects of the wind. So accustomed are we to associate with the wind these effects of the wind that when we see them we say we have seen the wind. Many physical phenomena are likewise "observed," not directly but through their effects. Thus, no one has ever seen an electric current. Yet from its effects we have a fairly extensive knowledge of electricity. So, even if we can not "see" atoms in the ordinary sense, we can study them by indirect means, particularly by the aid of X-rays.

Accordingly, when we "look at" our crystal of rock salt by aid of a beam of X-rays, we see first of all that the atoms of sodium and chlorine are arranged in regular rows, columns and layers, like a three-dimensional checker board, in which a white square is always next to or immediately above a black square. It is this regular arrangement of the atoms that causes the crystal form and makes it possible to split the crystal along a cleavage plane. From certain electrical data the distance apart of these planes

is known, with great precision, to be .000,000,028,14 cm, and it is this fundamental distance which makes it possible to measure the wave length of X-rays. Studies of this kind show that a very great many substances are crystalline. Thus ordinary lime, calcium oxide, has a crystal structure like rock salt. Many metals, such as copper, gold, aluminum, platinum, sodium, tungsten, iron, have a cubical arrangement of their atoms, something like rock salt; while others, such as magnesium and zinc, have a hexagonal arrangement. It is by studying their crystal structure that the engineer gains valuable data regarding the property of his materials.

However, not only can the positions of atoms in crystals be determined with certainty, but X-rays have furnished one of the most important tools in studying the makeup, or structure, of the atom itself. We "see," first of all, that the atom is made up of electric charges, or perhaps some prefer to say, of charged bodies. There is a central core, or nucleus, containing a positive charge around which are negatively charged electrons, probably in orbital motion similar to the motion of the planets around the sun. Studies made with X-rays have made it possible to determine not only the number of those electrons, but with some probability their arrangement. Thus sodium has eleven electrons; chlorine has seventeen; silver forty-seven, and lead eighty-two. These electrons are arranged in concentric groups or shells. Thus silver has an inner group of two electrons, spoken of as the K group, just as if Mercury's orbit were occupied by two planets instead of one. Next comes a group of eight electrons, called the L group, similar to what we should have in our solar system if there were eight planets revolving in orbits the size of that of Venus. Outside the L group comes the M group, comprising eighteen electrons, as if there were eighteen earths. Then, probably, another group of eighteen with still larger orbits. This makes a total of forty-six electrons. The remaining electron, since silver has forty-seven, probably revolves in an orbit outside of all these and is the electron which the silver atom uses when it wishes to make chemical combinations, such as the silver bromide of your photographic film.

When the atoms in the target of the X-ray tube are bombarded by the high-speed electrons from the filament, the impact is sufficient to dislodge from their orbits some of the electrons which an atom normally contains, and thus the electron system is seriously disturbed. In the process of returning to its normal state by capturing other electrons to fill the vacant spaces, the atom radiates energy, *i.e.*, emits the characteristic X-rays previously referred to. A piano string, when disturbed from its normal equilibrium position by being struck with the hammer, emits sound waves.

By studying the frequency of these characteristic X-rays, we can gain some very precise information as to the energy required to pull an electron out of an atom and therefore the amount of energy which the atom gives out when it gets the electron back. It requires less energy to pull from the atom an electron of the L type than one of the K type; and still less for one of the M type. Accordingly, higher frequencies are given out when an atom regains equilibrium after having lost a K electron than after having lost an L electron. In the target of the X-ray tube some atoms lose K electrons, others lose L electrons, etc. Consequently we have from a given target material a large number of characteristic frequencies.

These amounts of energy, in the case of a single atom, are of course not large. But if there were some known means of extracting a single K electron from each of the atoms of silver in a ten-cent piece, the energy which would be given out when the ten-cent piece returns to nor-

mal by capturing electrons would be enough to run a twenty-five-watt incandescent lamp continuously for three weeks.

Perhaps our great-grandchildren may find a way to make use of this storehouse of energy, and if so they will have ample reason to be grateful to those scientists of our generation who have helped to acquire this knowledge and to build these theories which are now of such fascinating interest.

WHAT IS AN ELEMENT?

By ROGER C. WELLS
UNITED STATES GEOLOGICAL SURVEY

FOR the benefit of any "listeners in" who may wish to know at once what I am going to talk about let me hasten to say that my subject concerns the chemical elements—not so much any specific chemical elements as the definition of an element and our reasons for classifying the elements by a series of numbers from 1 to 92.

To understand what is meant by a chemical element requires some idea of the scope of the science of chemistry. The chemist's particular field of study is the composition of matter of every sort—from the air we breathe to deposits dredged from the bottom of the sea. The chemist analyzes substances—that is, he separates them into simpler components. This sort of work has been going on for many years, but with all his separating he finds a few substances that he can not decompose into any simpler substances by ordinary chemical methods. These are the familiar chemical elements—the elementary substances of which all known matter is composed.

You will see that this view holds matter to be heterogeneous, even in its final analysis. But the idea that matter is more simple than this, that it is built up from a single substance, or at most from a few substances, is much older. The Greek philosophers have priority on this view, as they have on several other concepts in this field, such as atom, transmutation and chemical affinity. But their concepts were at best hardly more than suggestions, proposed with little or no experimental basis and bearing little resemblance to the ideas we now hold. On the other hand, like many other products of the fertile Greek mind, these earlier views have never lost their power to suggest questions and to incite investigators to put matters to a test and get at the root of things, so to speak.

Democritus, who lived about 400 B.C., was probably the first to think of the atom as the ultimate unit of matter, but it remained for John Dalton, over two thousand years later, to crystallize the idea by regarding the atom as a fixed weighable quantity of each element. The atoms of each element have a definite volume, called the atomic volume, and a definite weight, called the atomic weight. The atomic weights are of great assistance in calculating the proportions of elements in compounds and the proportions in which substances react chemically. For convenience, however, the atomic weights are expressed on a scale in which the atomic weight of hydrogen is taken as 1.[1] When the atomic weights of many elements were found to be exact multiples of that of hydrogen, Prout, another English chemist, suggested that all elements are really made up of hydrogen, and many determinations of the atomic weights of the elements have been made to see if they are exact multiples of any simple unit. A close approach to

[1] More precisely, the atomic weight of oxygen is taken as 16.

whole numbers is shown in a surprisingly large number of elements. The apparent exceptions are accounted for by the existence of isotopes, a word that will be defined in a moment.

The definition of an element as a substance that can not be decomposed into any simpler substance has been upset by studies of the radioactive elements. These elements decompose spontaneously. What the alchemist could not accomplish — transmutation — here appears as a natural process.

According to the usual definition of the chemist radium is an element, yet it decomposes into other substances which must also be recognized as elements. Some of these have very short periods of existence but their decomposition products prove that the atom must be composed in part of electricity or electrical energy.

Every one who uses electricity is familiar with the terms positive and negative. It is not so widely known, however, that the physicist, in considering electrical phenomena, thinks almost entirely of the negative electricity, and it is still less generally recognized, perhaps, that this kind of electricity consists of separate small units called electrons. The electron is the smallest entity known to science. It may be regarded as an atom of electricity, but its weight is certainly far less than the weight of even the lightest chemical atom and it is not generally considered one of the chemical elements. The equally small units of positive electricity that correspond to the negative electrons have received no special name.

Now the physicist has come to think of the atoms of the elements as composed, at least in part, of these units of electricity, as resembling, in fact, excessively minute solar systems with the units of negative electricity—the electrons—revolving in orbits about the positive centers, or nuclei. Some of the electrons may be located at the center, also, but a definite number are located in the exterior part of the atom, and the surprising relation appears that, beginning with hydrogen, the atom of which has only one exterior electron, the atoms of the other elements have two, three, four, and so on, up to ninety-two exterior electrons. Just as solar systems might be classified by the number of their planets, this relation furnishes a new simple numerical classification of the elements. The number of exterior electrons in each atom of any element is the atomic number of that element.

The atomic numbers of the elements are established by study of the X-ray spectra of the elements. Their order on this basis is, moreover, essentially similar to the order of the atomic weights, familiar to chemists as the Periodic System of the elements, by means of which the properties of scandium, gallium and germanium were predicted before the elements were discovered.

In the classification of the elements by their atomic number at least ninety-two seem to be possible, though the elements corresponding to numbers 85 and 87 are still undiscovered. Elements 43, masurium, and 75, rhenium, have been known scarcely a year; and 72, hafnium, not much longer. The existence of element 61, illinium, has only just been announced, as established by work done at the University of Illinois on its arc spectrum, its absorption spectrum and its X-ray spectrum. It is difficult to obtain these rarer elements in a pure state. You will see that spectrum analysis is an important method for differentiating and identifying elements. Some spectra are very complex, but this is not remarkable if the spectra are caused by rotation or vibration of the numerous electrons composing the different atomic systems.

As I said a moment ago, we now recognize ninety elements. But several of the elements thus defined appear in a number of forms that differ according to

their origin: such forms are termed isotopes. Thus element 82, lead, includes lead formed from uranium, ordinary lead, and thorium lead, whose atomic weights are 206, 207 and 208, respectively. No one has yet succeeded in separating these different forms of lead when once they are mixed, but they can be obtained separately from different minerals. The element chlorine, whose atomic weight is 35.46, has been partially separated into lighter and heavier portions, however, and it appears from the epoch-making work of Aston that many of the supposed elements are mixtures of isotopes, each isotope having an atomic weight that is a whole number on the present basis.

We therefore have two classes of elements—pure elements, each consisting of a single form, and complex elements, each consisting of a mixture of isotopes. The isotopes of the complex elements are not separable by ordinary chemical methods. Their chemical behavior is probably dependent on the number of the exterior electrons—that is, on the atomic number which is the same for all the isotopes of any given element. Differences in the atomic weights are probably explained by differences in the nuclei of the atoms.

It is only a comparatively short time since chemists held that the transmutation of one element into another would never be possible. The case is different now. Nature furnishes instances of transmutation in the radioactive elements and thereby discloses the most promising line of attack. It will be necessary to employ superchemical means, in order to penetrate and break up the nuclei of the atoms. Already it is claimed that hydrogen has been made from nitrogen, gold and platinum from mercury, and mercury and thallium from lead. But up to the present these results if obtained have been obtained only at great expense, and transmutation for commercial profit is certainly not yet to be expected.

Studies with the spectroscope indicate that in some of the stars only a few elements of low atomic number exist. The temperature on these stars probably so far exceeds anything within experimental range on the earth that even the atoms of the elements are dissociated into the very simplest combinations. When such stars cool more complex elements are formed.

From this brief discussion I think you will see that we now define an element as a substance that consists of matter all the atoms of which have the same atomic number. The element may have one form or several, depending on the structure of its atoms, but the atomic number tells us with what element we are dealing. Now the elements have many other properties also. I could go on and show that when we list the elements in a series in the order of their atomic numbers some of their properties recur at regular intervals; other properties do not show such a recurrence. But time prevents my going further here. The periodic system of the elements will have to be another story.

THE PROGRESS OF SCIENCE

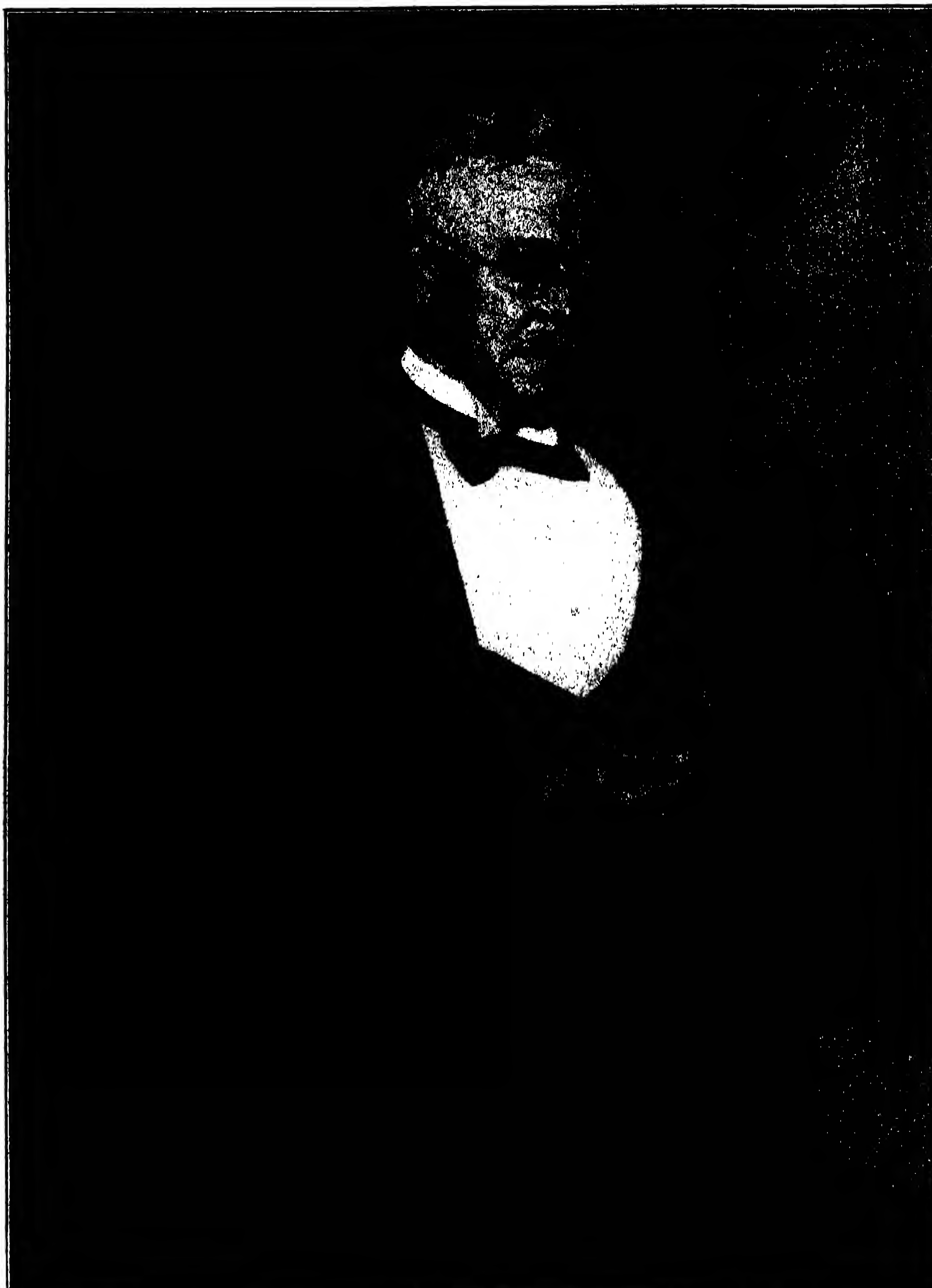
THE WASHINGTON MEETING OF THE NATIONAL ACADEMY OF SCIENCES

Science Service, Washington, D. C.

RECENT advances in atomic physics have led to a great increase in the understanding of internal conditions in the stars, Dr. Henry Norris Russell, of Princeton, reported to the National Academy of Sciences at its meeting on April 21. The outstanding problem is to find out where the heat radiated by the stars comes from and in what manner heat is liberated inside the stars. We now know that inside a star the atoms have their outer parts knocked off, but retain their individuality. And it is possible to calculate at what rate heat should escape from the interior to the surface,' and therefore how bright the stars should be, if we know how large and massive a star is and how much denser it is in the interior than at the surface. Existing evidence indicates that heat is probably produced by a slow transformation of matter into energy, after the manner first suggested by Einstein. If all stars were composed of exactly the same material, stars of the same mass would be similar, not only in brightness, but also in size, color and temperature. This is not a fact, and it follows that some stars must contain more than others of the "active material" which is the source of heat. The life history of a star depends upon the proportion of active material in its composition. If, as seems probable, this originally forms the larger part of the star's mass, a star of large mass will start as a red giant, gradually become hotter and whiter, and finally cool down and end as a faint dwarf. Stars of smaller mass may begin their careers as dwarf stars without ever passing through the giant stage.

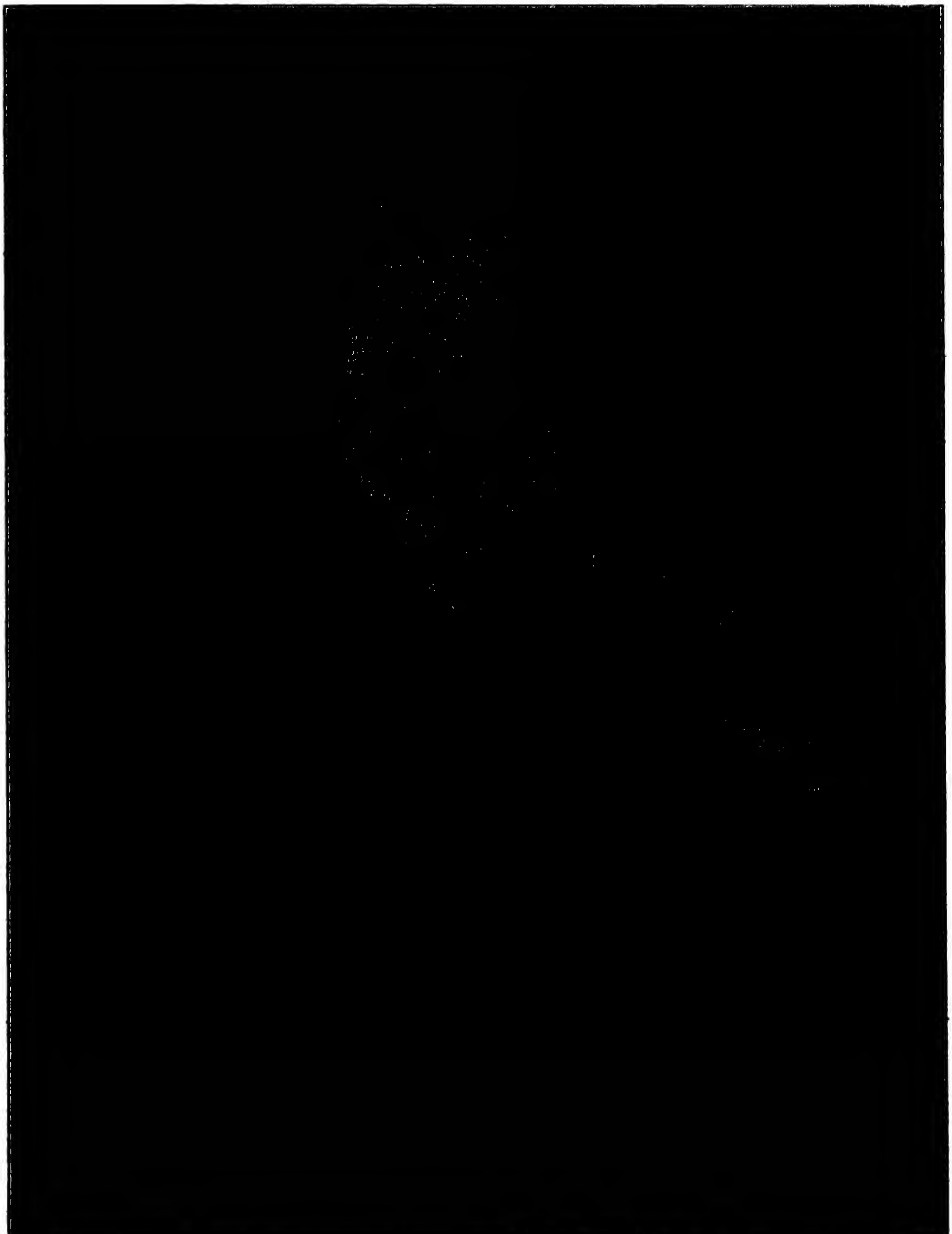
METHODS of measuring and weighing stars so distant that their light takes hundreds of years to reach us were described by Professor Joel Stebbins, director of the Washburn Observatory of the University of Wisconsin. Observations with the spectroscope reveal motions of certain stars which can be explained by their having large companions or planets. The periods of revolution of many of these attendant bodies are very short, even as small as one or two days. By choosing the proper time for light measurements, it is found that among the cases known in advance to be favorable fully one half of these double systems present eclipses as viewed from the earth. A study of the variation of the light of a star during an eclipse makes it possible to calculate the diameter of both the bright star and its dark or faint companion. As an illustration, it is noted that two stars moving in space parallel to the stars of the Big Dipper, and presumably belonging to that system, have each been found to have attending satellites. Each of the bright bodies is twice as heavy and gives one hundred times as much light as our sun.

MOTION of stars through space is not a random hit-or-miss motion, like a swarm of gnats, but many stars are moving along in parallel streams. In fact, such star streaming is a common phenomenon, according to a paper presented by Professor Frank Schlesinger. The Yale Ob-



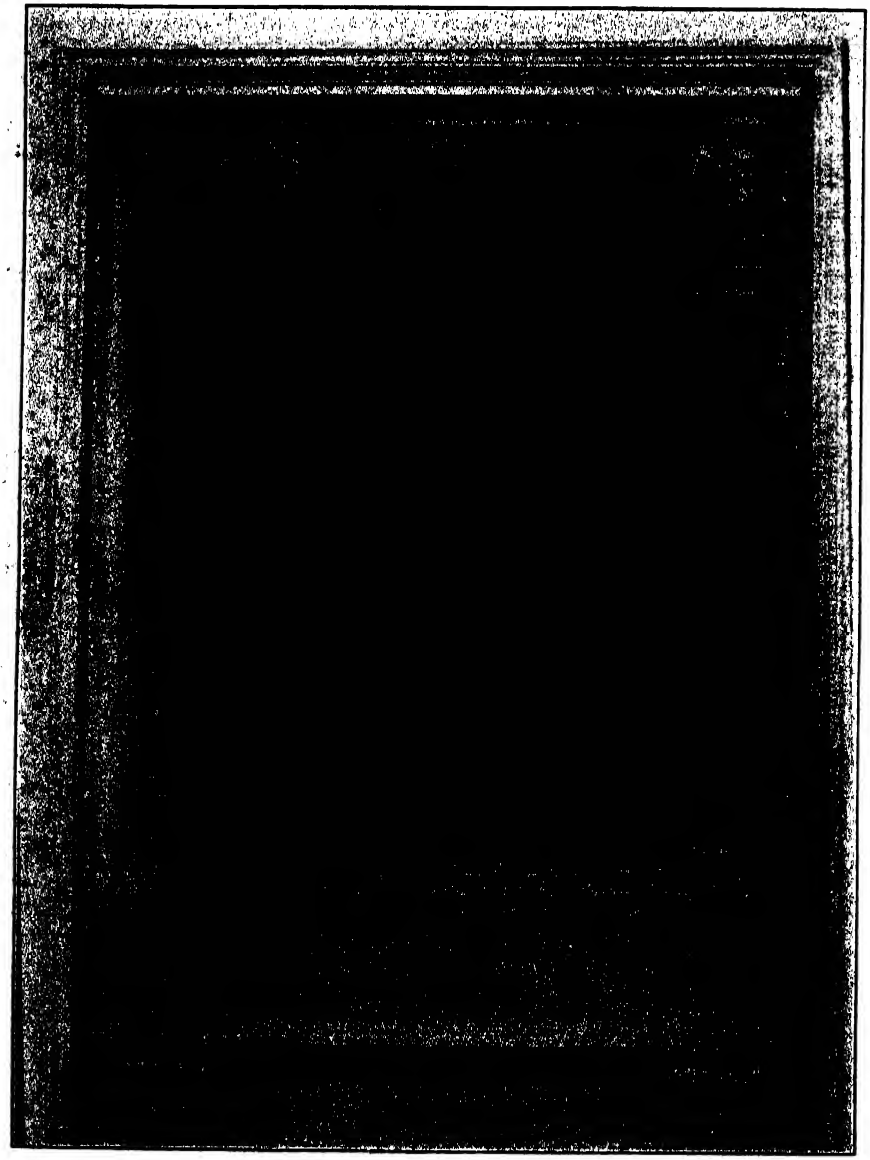
DR. WILLIAM BERRYMAN SCOTT

BLAIR PROFESSOR OF GEOLOGY AND PALEONTOLOGY AT PRINCETON UNIVERSITY, 1884, WITH THE HAYDEN MEMORIAL MEDAL AWARDED TO HIM BY THE ACADEMY OF NATURAL SCIENCE, PHILADELPHIA.



DR. HARVEY CUSHING

MOSELEY PROFESSOR OF SURGERY IN HARVARD UNIVERSITY AND SURGEON-IN-CHIEF OF THE PETER BENT BRIGHAM HOSPITAL, TO WHOM HAS BEEN AWARDED THE PULITZER PRIZE FOR HIS "LIFE OF SIR WILLIAM OSLER." THE PHOTOGRAPH WAS TAKEN IN FRANCE, WHERE DR. CUSHING WAS COLONEL IN THE MEDICAL CORPS OF THE UNITED STATES ARMY.



MEMORIAL TO JAMES DEWAR

RECENTLY UNVEILED IN THE ROYAL INSTITUTION, LONDON, WHERE DEWAR CARRIED ON HIS IMPORTANT CHEMICAL WORK, INCLUDING THE LIQUEFACTION OF GASES.

Wide World Photos.

BUST OF LUTHER BURBANK

TO BE DEDICATED TO HIS MEMORY AT SANTA ROSA, CALIFORNIA, WHERE HE CONDUCTED HIS WORK ON THE CREATION OF NEW TYPES OF PLANTS. THE SCULPTOR SHOWN IN THE PHOTOGRAPH IS MR. ROGER NOBLE BURNHAM, OF LOS ANGELES.

servatory, of which Dr. Schlesinger is director, has recently issued a catalogue giving the motions across the sky of over 8,000 faint stars in a section of the northern sky. Studies of these motions have shown that stars separated by great distances are, in many cases, moving at the same speed and in the same direction. Though it will be necessary to find out how rapidly these stars are moving towards or away from the earth before it can be determined whether they are actually moving in parallel paths, such cases occur so often that they can not be due to chance.

CAN the ambition of children to "grow up" faster, and of all of us to be big and tall, ever be realized by a future generation? Perhaps, if human beings can learn the trick that seems to have been mastered by rats in the laboratory of Dr. Thomas B. Osborne and Dr. Lafayette B. Mendel at the Connecticut Agricultural Experiment Station. A breeding stock of experimental animals under their observation has "speeded up" the growing process by nearly a third during the past half-generation. In the course of the past fifteen or more years they have had the opportunity to secure records of the

rate of growth of several thousand rats under controllable conditions with respect to diet and environment. The animals have been bred from laboratory stock without any introduction of "new blood" within the past ten years. The stock diet during this period has presumably remained essentially the same so that changes in the average rate of growth may perhaps be properly attributable to the effects of selective breeding in the attempt to secure vigorous animals for experimental use. A noticeable increase in the average rate of growth has in fact resulted. For example, the average time required by male rats to grow from two ounces to seven ounces body weight has gradually decreased; it was approximately 94 days in 1912; 89 days in 1913; 70 days in 1919, and 67 days in 1925.

THOUGH a baby, or a small boy, may "grow like a weed," his growth does not go on at a steady, unvarying rate, but in three grand spurts, which overlap each other, making the "growth curve" which scientists plot to measure the rate into a very complex affair. Dr. Charles B. Davenport, of the Carnegie Institution of Washington, spoke of his studies of this problem. The first period of maximum growth rate is at the time of birth. The baby grows fast, as everybody knows, but the rate of growth falls off for several years. Then it starts to speed up again and, in the case of boys, at least, it reaches a climax at about eight years—that embarrassing time when a boy's knees simply will not stay inside their proper garments. A second slowing-down follows, and then a second speeding up, the rate of growth reaching its maximum at fifteen—the "all hands and feet" period, when the youth is "shooting out of his shoes." The three growth-spurts correspond closely with periods of greatest activity of some of the internal glands. The first and second periods of growth correspond with activity on the part of thyroid and pituitary glands, respectively, whose secretions are known to be growth-promoting. The third cycle is a fundamental one, underlying the others, and probably represents some more general growth stimulus exerted from the time of the first existence of life until growth stops altogether.

A METHOD of complete denervation of the heart of an animal which has facilitated study of the effect of emotions on the body was described by Dr. Walter B. Cannon and Dr. S. W. Britton, of the Harvard Medical School. The method of cutting off the heart from the nervous system leaves the adrenal glands, which play so important a part in emotions, as the only glands affecting the heart action. When fear or anger is aroused, the adrenals secrete adrenin, which makes the heart beat faster and speeds up the body mechanism, so that there is more energy for fighting or for escape. It was previously known that the denervated heart is extraordinarily sensitive to adrenin. Such a heart would beat faster when adrenin was present in the blood circulating through it in the ratio of one part in more than a billion. By their method, the two physiologists found that even if the animal changed from lying down to walking, the heart rate increased 10 to 15 beats a minute. Emotional excitement without much muscular activity increased the rate about 20 beats a minute. And in aggressive rage, when there was great muscular stress, the heart was sometimes accelerated as much as 70 or 80 beats per minute.

THE living tissue of plants sometimes responds to the stimulus of disease, not by producing the characteristic diseased growths, but by producing normal kinds of tissue in the wrong place, according to Dr. Erwin F. Smith, of the U. S. Department of Agriculture. Dr. Smith,

Wide World Photos.

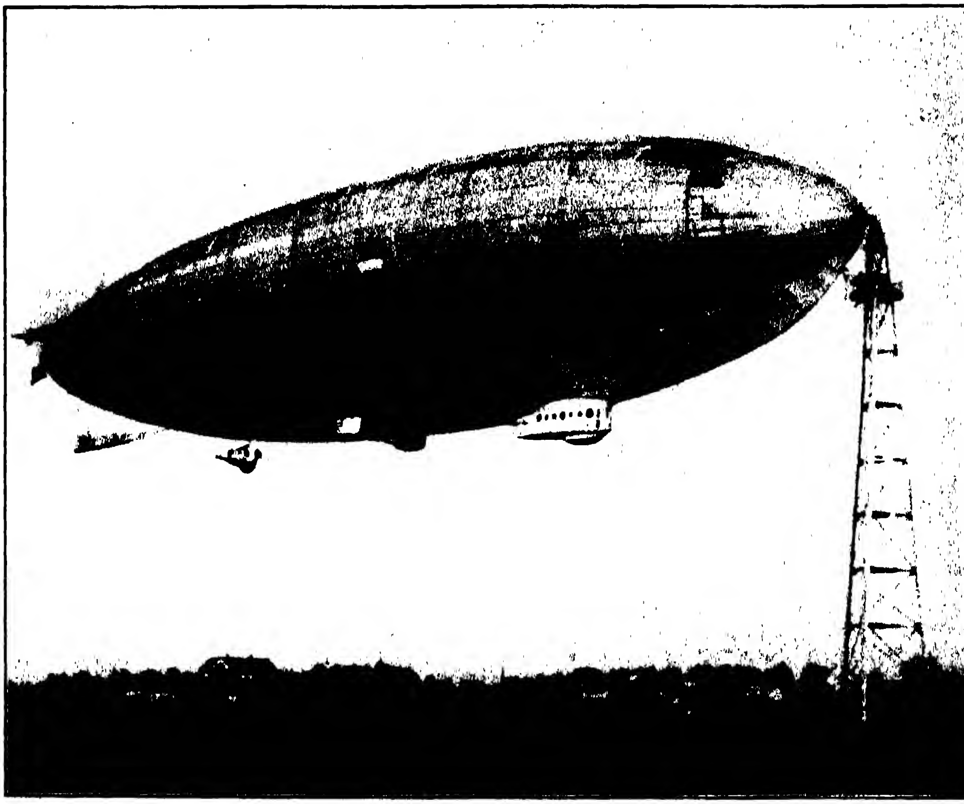
LIEUTENANT-COMMANDER R. E. BYRD, U. S. N.

AT THE SEXTANT OF THE GIANT FOKKER AIRPLANE IN WHICH HE REACHED THE NORTH POLE.

who is an authority on the crown-gall disease of plants, injected some of the organisms that cause this malady into sunflowers. They responded by growing extra rays, or petals, in the disk of the sunflower head instead of around the edge, by forming cavities within the plant, lined with the hair cells normally found on the outside, and by forming woody tissues in the pith, where normally nothing of this kind is found. Dr. Smith points out these phenomena as striking examples of the effects upon young growing tissue of changes in environment; semi-mature tissue, he says, does not show such effects.

WHEN drops of blood are cultivated outside the body some of the white blood cells, which normally act as guards against germs, undergo considerable change. Dr. Warren H. Lewis, of the Johns Hopkins University and the Carnegie Institution, in his paper said some of these mononuclear cells develop into macrophages, the wandering cells of the body that combat disease, while others become epithelioid cells similar to those in tuberculous lesions. Mononuclear blood cells probably undergo similar changes in the body. The tumor cell in one variety of rat sarcoma has been found to be a modified mononuclear white blood cell of the epithelioid type. Pure cultures of such tumor cells inoculated into a rat produce tumor, and cultures from the tumor so produced behave like that of the original.

CAPTAIN ROALD AMUNDSEN



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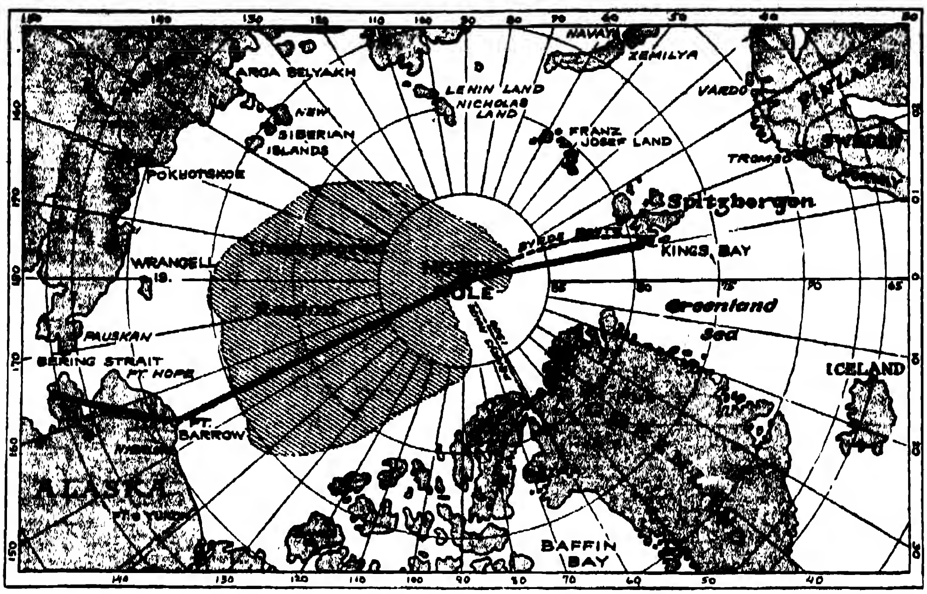
THE NORGE AT OSLO

THE "NORGE I," MOORED TO THE MAST AT EKEBERG, OSLO, THE AIRSHIP OF THE AMUNDSEN-ELLSWORTH EXPEDITION TO THE NORTH POLE.

AN effort to determine the fundamental differences between sexes has been made by studying bread moulds. This group of fungi has distinctly sexual type of reproduction, but on account of the similarity in appearance of the sexes it has been impossible to tell clearly which was male and which was female. Since the sex cells are equal in size and the developing offspring are apparently nourished equally by both sexes these fungi are especially suited for study of this problem, according to the paper by Dr. Albert F. Blakeslee, of the Carnegie Station for Experimental Evolution. Investigations carried on by him and Miss Sophia Satina at the Genetics Laboratory at Cold Spring Harbor show that the females of the higher plants make a more active response to biochemical tests than males. The biochemical test to determine sex in man, made by mixing certain reagents with the blood, has been found applicable to plants, and over 90 per cent. of correct sex identifications have been made by this method. The bread moulds have been found to react chemically to these tests in the same way as do the higher plants and animals, thus enabling us to ascertain which are male and which are female.

How nitrogen can be changed to fluorine and then to hydrogen and oxygen when hit by the rapidly moving nucleus of an atom of helium was de-



Courtesy of the New York Times.

THE NORTH POLAR REGIONS

THE DOTTED LINE SHOWS THE COURSE FOLLOWED BY LIEUTENANT-COMMANDER BYRD TO THE POLE. THE HEAVY BLACK LINE SHOWS THE COURSE FOLLOWED BY THE NORGE TO THE POLE AND THE PROPOSED COURSE FROM THE POLE TO NOME.

scribed by Dr. William D. Harkins, of the University of Chicago, who has succeeded in photographing the changes. In a closed chamber containing very moist air, the moving atoms are not visible, but they have the property of condensing the water vapor along their path into a long narrow cloud, so that their path can be traced and when one atom hits another, a forked line is seen, due to the fact that they rebound. This process was invented by Professor C. T. R. Wilson, of Cambridge University, England. A photograph taken by this method indicates that a fast helium nucleus strikes the nucleus of a nitrogen atom, possibly forming the nucleus of a fluorine atom. This almost immediately explodes to give a fast hydrogen nucleus and the nucleus of an oxygen atom. Efforts to convert mercury to gold were unsuccessful. An X-ray tube was used to shoot electrons at 138,000 to 145,000 volts into mercury. If any one of these electrons were to add itself to the nucleus of a mercury atom, without driving out another particle, an atom of gold would be formed. If any electrons attach themselves in such a way, less than one in a billion does so, since no trace of gold was found in the mercury bombarded.

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